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Science Review

COOPERATIVE STATE RESEARCH SERVICE U.S. DEPARTMENT OF AGRICULTURE VOL. 8 NO. 4

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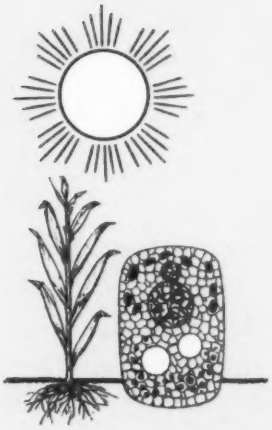

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The Corn Blight Saga

When the corn blight scare was at its peak late last summer, there was a noticeable tendency by some agriculturists to adopt a defensive attitude, as if something had been remiss in corn disease programs and excuses needed to be made. The situation resembled somewhat the case of a straight-A student who suddenly gets a low grade and feels obliged to do some explaining to his elders. The parallel ends there, however, because in general the defensive attitude had little or no connection with quality of performance.

In retrospect, this reaction resulted largely because all science in America today is pretty much on the defensive. The average person has been conditioned to spectacular successes, and when something happens that seems to be less than a flawless performance, the mood becomes critical.

Although we agriculturists have been told that it is unwise to bask in the glory of past successes, I wonder if public attitudes would be different today if the full impact of the hybrid corn story were better known and better understood. Are there still ways to get this message across without implying a defensive attitude? Will we grasp the opportunity that will surely come in the months ahead to tell how plant breeders and pathologists met the *Helminthosporium maydis* challenge?

Incidentally, it was reassuring to be exposed to the mood of optimism of the two principals in this issue's corn blight piece. One gets a much deeper appreciation of a problem area when all the facts are known and the issues are brought out into the open. We can be thankful that somewhere along the line certain parties had the foresight to set up long-range research plans and policies unrestricted by hard and fast cost-benefit ratios. Here is one area of science endeavor, at least, where it is better to have acted rather than to be forced to react. The agricultural sciences—so deeply rooted to the welfare of man—cannot afford to be in such a bind.—W.W.K.

AGRICULTURAL SCIENCE REVIEW is published quarterly by the Cooperative State Research Service, U.S. Department of Agriculture, Washington, D.C. 20250.

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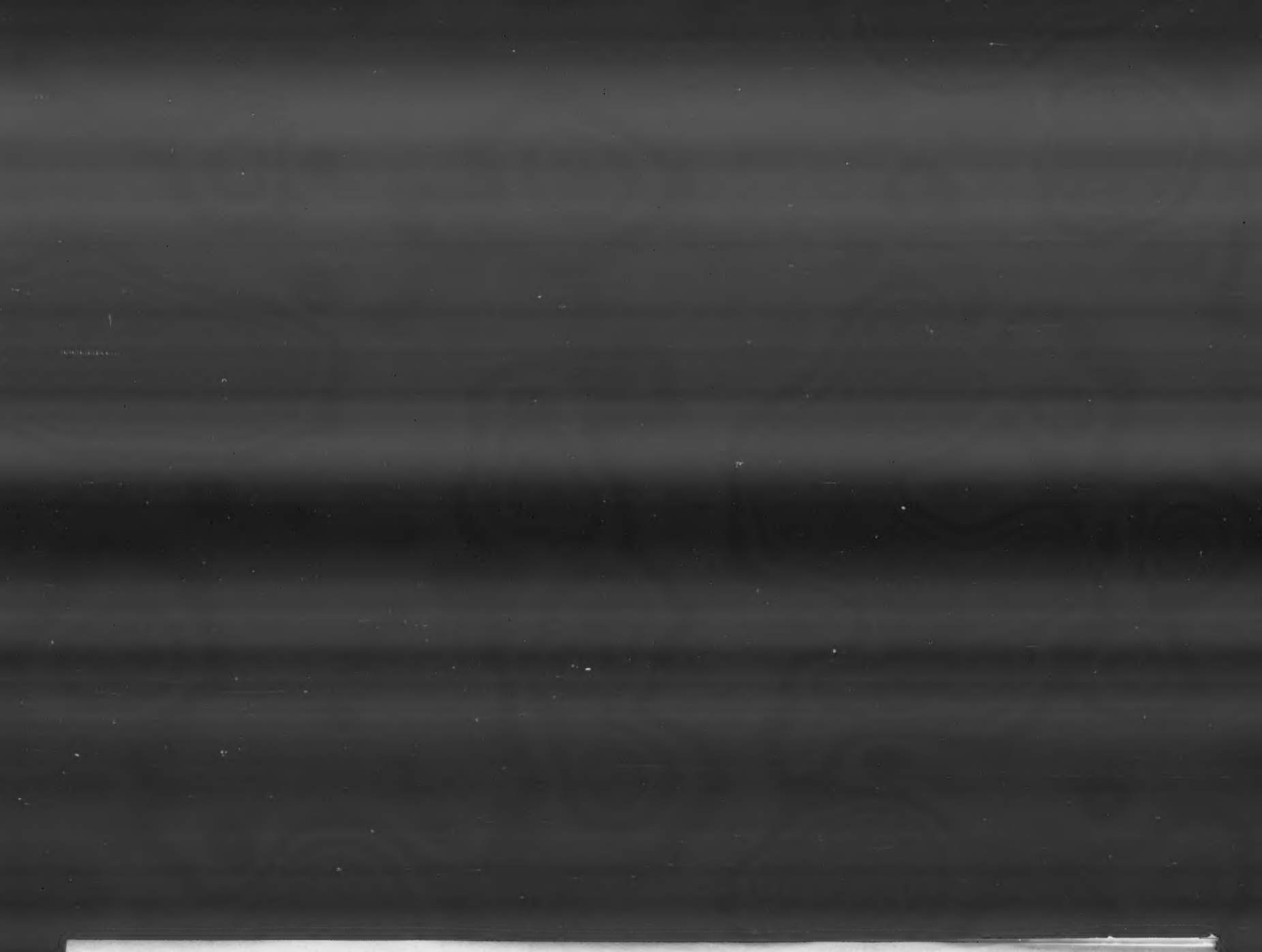


A COLLOQUY ON CORN BLIGHT

JOHN F. FULKERSON AND JOHN M. BARNES

LAST fall after the initial concern about the southern corn leaf blight epidemic had lessened, the editorial staff of Review *decided that the time was right for a quiet, thoughtful—and perhaps philosophical—discussion about the situation. We deliberately chose dialog, or colloquy, as a communications form best suited to accomplish our purpose. The two principals—Dr. Fulkerson and Dr. Barnes—were chosen not only because they were well-qualified to speak authoritatively on the subject from a national viewpoint, but also because the editor knew they were capable of injecting the "feast of reason" into their discourse.*

The questions, posed by the editor of Review, *were asked mainly to provide a takeoff point for an opening of the minds. Readers should understand, however, that the colloquy is not intended to encompass all facets of the subject, because corn blight really represents a "system of things." Instead, we hope it will stand as a prime example of some of the objectives of this journal—to raise critical issues about a vital area of interfaced concern in agriculture, to point out deficiencies in the knowledge, to stimulate inquiring minds.*

PERHAPS we might begin this dialog with a brief résumé of the history of plant blights.

Dr. Fulkerson: We've always had blights of course. Cases have been documented since early Biblical times; some of them were quite serious.

There is considerable evidence that "manna" was really a bloom of a well-known plant fungus—an edible one. There are also archeological records dating back further than Biblical times showing that blights—major plant epidemics—had significant effects on man's early crops, and hence his coping with life about him.

Dr. Barnes: Blights apparently affected early man in other ways too. For instance, there was the Festival of the Rubigalia—worshipping the gods of rusts in cereals. There are many recorded instances in Egypt and the Middle East, showing national concern about blights, rusts, plagues, mildews—these are the terms that have been used since the time of Theophrastus.

We also have evidence from fossilized plants showing that pathogens had been attacking plants long before man ever began walking upright. These are indelible evidences.

Fulkerson: Then in modern times, of course, we have well-documented records of blight epidemics. The potato blight of Ireland is a classic example. A quarter of million people died as a result of it, and

it caused untold additional miseries. An entire sociological structure was changed, one facet of which was the massive migration to the Western world.

How was that blight epidemic finally controlled?

Barnes: Largely through the use of Bordeaux mixture. Of course 10 or 15 years later the disease had about run its course and people were no longer relying on potatoes as a staple item of diet. Eventually, this fungicide helped bring potatoes back into European diets. Later on, Bordeaux mixture was also tested for use on other diseases and proved to be a satisfactory control for many of them.

Fulkerson: There are several interesting sidelights on this classic example of a blight. Oddly, a number of the men who followed the disease were clergymen. They belonged to what we would call "garden clubs." But they were serious clubs, and they began to devote much of their time to such plant problems. One of the club members noted that potatoes grown near the seacoast were unaffected by blight. Thus, they first began to associate blight with climatic factors.

We must remember that at that time no one had a firm concept about the germ theory of life—and its disease. The influence of Pasteur, Lister, and others was not yet strongly felt. Oddly, a man of the church—Berkeley, in England—brushed aside some of the popular theories of the day that blights and other afflictions, famines, had quasi-religious connotations. He was keen enough to note that lesions on affected plants had signs of living organisms.

Have there been any cases of blight that have proved to be too great a challenge for man?

Fulkerson: In one sense, yes, there have been some—but only in a restricted context, either from a geographical or a time framework. For example, coffee rust drove the culture of coffee out of one area of the world into another. Some highly desirable varieties of alfalfa were driven out of certain cultural areas because of bacterial disease. Fire blight forced much of the pear and plum production out of the eastern United States. To this day, we still work on some diseases which, if they were not known to us earlier and we were suddenly looking at them today, we would probably say they were quite epidemic in nature. Take fusarium wilt, for example. In the past, we've had some very substantial losses from fusarium. To a degree we control it here and there, and in that sense it has not proved to be too great a challenge to man, although losses are still rather large.

Barnes: In general, as we do our research on disease and pest control, we are aware of the potential for epidemics but we're not preoccupied with fear. Although the potential for a major epidemic such as fire blight of orchard crops is always with us, we weren't as well prepared for the southern corn leaf blight epidemic as some persons warned 5 years ago that we should have been. That dynamic system "out in the field" works with its own changing sets of conditions, rolling the dice, if you will, for the right combination of environmental conditions—then you have all the makings for a major outbreak of disease or infestation.

Fulkerson: There are similar parallels in diseases of man—influenza for example. Some of these we eventually do control, of course—polio is one.

Barnes: The nature of the research climate is a factor, too. For example, right now we are in a period where impressive, organized research plan-

ning is focusing on the immediate needs of people . . . on the problems of environment . . . away from production-oriented research. But how far can we afford to swing in this direction? Today, we see people wringing their hands when something like southern corn leaf blight comes along. We do have to maintain a base in production-oriented research—a base in science—and we have every reason to believe that we will have to continue working with significant resources against these potential epidemics and related problems.

Do you mean, then, that this situation does not reflect any shortcomings of the discipline of plant pathology, but rather that it represents a pattern or a trend of society?

Barnes: Yes. It is a trend toward focusing on certain areas, which society deems important at the moment.

It seems that lately we've been hearing about more and more cases of blight outbreaks—the one we're talking about now, of course, and then there's the coffee rust in Brazil . . . . Could this mean that we're on the verge of an upsurge in fungal diseases of plants?

Fulkerson: First, we should make it clear that not all epidemics are caused by fungi. Bacteria are responsible for some too—as are viruses and nematodes. But to get back to your comments . . . . I would approach this in two ways: First, I would not be drawn into saying that we could expect much increase in fungal diseases—either worldwide or locally. From a philosophical standpoint that is. As a firm believer in evolution, there is no reason for me to say that the whole concept of biochemical evolution is going to be thrown out the window. I cannot accept the idea that one category of living organisms—lower plant life characterized as fungi—basidiomycetes, ascomycetes, bacteria, etc.—after all these thousands and thousands of years, would suddenly and collectively take on an unusual ability to be able to become so preeminent that they would become epidemic. The germ plasm that is in the host made its peace in the brushfire of biochemical evolution eons ago.

Now, of course there are possibilities, because of man's intrusion, of having some increases when man alters things—as in our present case where he religiously plowed in T-germ plasm in corn as fast as he could in the middle and late 1950's—he set himself up for it. Another smaller example that no one hears much about would be the thousands of miles of windbreaks of a special poplar out in the North Prairie States. Those who worked that out have always sat on the edge of their seats wondering when somebody would discover that this plant holds resistance to only one single rust fungus that has depleted other types of poplar all over that area—just that one strain. The point is that the other strain has never occurred in that area. But it could and they never denied that it could. They have always pleaded for broader resistance, but industry and breeders said, "This is so good, let's not fiddle around."

They said the same thing about T-germ plasm: "When you can produce 180-bushel corn so easily with T, let's push that hard and get the mileage." So you are getting over to another area of judgment that has nothing to do with science, that is, it's not a science rationale *per se*.

Barnes: I will have to qualify that question too. You have to look at the changes that are going on now in the present context, recognizing that ongoing research will contribute to tomorrow's answers, but will not provide magical predictions for the future.

If you want to go back to the work of Berkeley as a base for the breakthrough on the control of late blight in potato, I would say that we are up against the same kind of problem in trying to predict what might come in the next 5 or 10 years. We have no credible means for making a firm statement as far as expecting the environment to change, the so-called warming trend, or increases in relative humidity.

Did geneticists know there was a possibility that reliance on T-background would cause trouble later on?

Fulkerson: Yes, geneticists knew it. Pathologists were aware of it too, and at least one of them predicted 5 years ago that this would happen. Last year three experiment stations held serious discussions about the status of corn blight—similar to the ones we held in USDA last fall. They expressed concern about the potential for increase in this disease in 1969, and several were conducting investigations at that time.

Barnes: We realize that we have to focus more on the pathogen itself. We developed plants with these single loci—vertical resistance—and we were rewarded with a spectacular degree of resistance to a particular disease, a particular strain. There are scientists of course who reason that we should settle for a broader base—a less spectacular degree of resistance, a so-called horizontal resistance.

That sounds like a logical approach. What is the general reaction among plant pathologists and geneticists?

Fulkerson: There is another side to the whole argument—and maybe a very valid one. Both corn and soybeans would be good examples. In the early 1960's the researchers who had successfully developed a soybean variety with high resistance to cyst nematode argued that it should be released to growers. We knew, of course, that if you grew that kind of germ plasm you would very soon force the other side of the population. A counter argument was, of course, that the resistant variety would enable growers to produce nematode-free soybeans for about 6 years—which they eventually did, and reaped some economic benefit. Whether the good obtained from the shortrun benefits will outweigh the harm, or potential harm generated by this process, can be questioned.

In defense, the same kind of reasoning applies to the use of the T-strain cytoplasm in corn. This risk is perhaps one of the costs that we have to bear. We can't overlook the fact that the use of T-strain hybrid has given us some great benefits. One of the major ones is lower food cost. Meat, for example, would be much higher if we didn't have an abundant supply of relatively low-cost corn.

As to the philosophical question as to whether insects and diseases will take over the world—I cannot believe that. I admit that man makes some mistakes. You would have to assume a complete aberation from the concept of biochemical evolution of life. The fact that evolved life appears to have existed on this planet for 21 billion years certainly seems to support the theory of biochemical evolution of life. To me, the sudden preeminence of pathogens would deny the whole concept of biochemical evolution.

Barnes: Yes, it would deny also that there is a response syndrome on the other side of the picture—that the aggression would come only from the pathogen and that the host plant (and the scientist working on the host plant) would not in some way come up with the ability to respond and lessen the effects of that pathogen.

In other words the fungus will always be with us—but will never be able to take over?

Fulkerson: That's probably right. They never took over before we were here, except in isolated situations in both plant and animal life.

You mean that it is a part of the "scheme of nature?"

Fulkerson: Yes, if you want to put it that way. The cycads—some of our earliest plants—made it.

The cycads? What are they?

Fulkerson: Those are the giant, fernlike plants associated with the dinosaur age. We have an excellent example of another ancient form right here in front of the USDA administration building—a *Ginkgo biloba* tree—a magnificent specimen. The ginkgo is a very ancient source of higher plant-germ plasm. Some of the embodiment of the ancient dinosaurian cycads is in *Ginkgo biloba*—in the sense of the immortality of germ plasm. It made its peace with bacteria, fungi, nematodes, and insects. A most interesting tree—the ginkgo.

What has been our most reliable weapon in fighting outbreaks?

Fulkerson: Some very knowledgeable people say that the answer is breeding resistant varieties.

Barnes: Others—very knowledgeable too—would argue that chemicals are the only answer.

Chemicals are used on sweet corn in Florida, are they not?

Fulkerson: Yes. They have used carbamates to fight yellow blight and do it very beautifully. It does a fine job on sweet corn and not just in Florida.

There are other concepts—interesting ones too—

that have not even come close to being capitalized on. For example the notion that almost no plant breeding for disease resistance is done for both resistance to the pathogen and resistance to highly selective biocides and growth modifiers. Other than by an opting-out process, we've really done very little to breed plants highly resistant to certain biocides. Or, to state it differently, to make them highly susceptible for use. The two are not mutually exclusive. Also, no one has ever isolated a southern leaf blight (*Helminthosporium maydis*) lesion from a corn leaf without finding certain bacteria present. We are not talking about just pathogenic bacteria—but bacteria. When you stop to consider the millions and millions of lesions of the organism this year—and the fact that we know so very little about the role of bacteria found in conjunction with the lesions—this in itself offers some possibilities.

There are a number of examples of diseases—black root rot of sugar beets is one—on which large sums of money have been spent in seeking ways to combat it. This disease has been a very serious problem for sugar beet growers both in Europe and the United States.

Now, if you take a seed of one of the very old varieties highly susceptible to the disease, and grow a plant under germ-free conditions and inject the plant with a pure culture of this fungus, the disease does not develop. You would think then that this variety is resistant to root rot. You might ask then why we have spent so much research money to protect growers from black root rot. *But,* if you take any one of several isolates of a well-known soil bacterium, which is not a pathogen, and put that isolate in with it, black root rot of sugar beets will occur—and quickly.

Now, we are not being so blunt or so dramatic to say that this is the answer to corn blight. What we are saying is that there are organisms that help pathogens make a go of it; these are very important and can be treated much more easily sometimes than the pathogen can. In order to do this, of course, the plant must be tailored to be highly selective to a particular biocide. This sort of thing is not being widely done.

Barnes: One thing interesting to speculate about is that we may be working on the wrong side of the problem in breeding for resistance. We must remember that plants survive from their epicenter because of innate resistance, and therefore susceptibility is a development—an evolutionary phenomenon. This susceptibility has been a result of an intensifying combat between the host and the parasite or the pathogen.

So it behooves us to look more closely into the nature of susceptibility and to breed for reduced susceptibility to a disease, rather than pulling out genes for resistance. We do have dramatic examples of our ability to pull out genes for resistance. The nature of susceptibility is one thing I think we can take a closer look at, particularly the biochemical factors that will support a fungus within the plant and govern the response of the plant to an early invasion. Some examples are factors that result in a differential food source or a differential cell breakdown rate.

In a recent Review article, a plant pathologist said that the nutrition of a plant can affect the degree of susceptibility of a plant to a disease. As an example, he said that well-fertilized wheat plants are more susceptible to rust than those grown on poor soil. Is there any clue here to better control of blight?

Fulkerson: In the case of corn blight it appears that the exact opposite is true. It has been pointed out in one key corn-producing State that in well-fertilized and well-irrigated corn, the damage from southern leaf blight is much less. I think, though, that some generalizations and qualifications will have to be made on both sides of the fence.

Some years ago a disease known as Granville wilt hit much of the flue-cured tobacco crop in the South. It was literally wiping out the $500 million flue-cured tobacco crop. Plant pathologists and breeders worked hard on a program to develop a resistant variety. Eventually they succeeded. It has been said that the economic return from the crop for only 3 years was equal to what it would take to run the entire experiment station for a whole decade. In this particular case, good nutrition in the plant actually resulted in a disease condition of epidemic porportions.

But there are scores of situations where, when the plant is growing under stress, the disease can take over. The same condition is true in man: When he is undergoing certain stress conditions, he is more susceptible to some diseases. There are many examples of plant diseases that do not reach epi-

demic proportions unless stress is present.

Barnes: Because we don't generalize about the status of nutrition, we can't, therefore, generalize about the fundamental phenomenon that is taking place. When do you evaluate the status of a plant's nutrition? Even the act of bearing fruit is considered a stress factor. But of course there are others, such as drought or excessive moisture, that affect the uptake and translocation, and therefore, the metabolism of mineral elements and organic moieties. Cell function is an important criterion. The proportion of living cells in a cornstalk is apparently an important factor in the propensity for development of stalk and root rot.

This leads me to another problem of stress: What impact can we expect from these leaf blights and the ear rots on subsequent root and stalk rot of corn later in the season? The nature of stalk and root rot is that it is a disease of maturing plants. Therefore, when there is a period in which the process of senescence is accelerated, then the groundwork is laid for a potentially severe case of stalk and root rot. It's a disease of plants that has largely a saprophytic aspect—that is, microflora flourish best in dead and dying stalk tissues.

Fulkerson: Yes, such a condition can aggrevate the situation where corn is not harvested for silage, because if a cornstalk is down, the corn harvester obviously has difficulty in picking the ear.

What is the time of greatest stress of corn?

Barnes: This would be following anthesis and fertilization when there is a rapid synthesis, mobilization, and movement of metabolities through the plant to the ear to provide a food source for the fertilized ovule. That is, when the ear starts filling out, a drastic change takes place in the plant.

Was it possible that the prevalence of bad weather generated by hurricane Celia occurred at the time of greatest stress in the corn plant?

Barnes: It could have been that—a fortuitous combination of conditions associated with a massive tropical disturbance, which may have carried spores from southern cornfield to the northern corn production areas.

Fulkerson: What we are talking about here is a disease in which there is a nearly straight line function between sporulation and spread of the disease. So when you have highly favorable climatic conditions, the potential for increasing the disease rises, because of the production of millions of spores to be carried into an area where there is susceptible

germ plasm and weather conditions favorable for an epidemic. There are many plant diseases where this is not so—that is, no such close correlation between sporulation and disease.

It is known whether or not the spores of the Helminthosporium maydis *overwinter?*

Barnes: There is some controversy over this. Some authorities say that the severe winter weather in northern latitudes will kill spores of the southern corn leaf blight fungus, and therefore the potential for disease incidence in the following year will decline. Others state that we cannot be sure whether spores of the corn blight fungus will overwinter—much less those of race T. Workers in Pennsylvania and Nebraska are doing some research this winter, expecting to learn more about the degree of survival of the spores of race T.

Has much research been done on this aspect of corn blight?

Fulkerson: Very little.

If the spores do overwinter to any extent, does this mean that we will have an epidemic next year?

Barnes: I would say the potential is there only if weather conditions favorable to the disease should occur next year. I think the potential for an epidemic can be decided upon, that is, the propensity for secondary infection—a continuing or sequential development of the inoculum. The southern corn leaf blight fungus, you see, has a tremendous spore-producing capacity. If the southern cornfields were, in fact, the source for the secondary epidemics in the northern cornfields, then those who make recommendations to farmers in the South might say that we should turn to normal cytoplasm seed or apply protective fungicides on the seed fields. The former possibility is remote because seed is marketed regionally according to specific maturity-class requirements—that is, there would be no shifting of a Corn Belt seed market to Southern States. However, I understand that only 40 percent of the 1971 seed will be normal cytoplasm. Therefore, because of the innate susceptibility of the T-cytoplasm, and because about 60 percent of the seed planted will be of the susceptible T-cytoplasm, I think the use of protective fungicides may become an imposing reality—at least for the 1971 crop.

Fulkerson: We have to also consider the possibility of mutation and new combinations—new strains developing. Take wheat rust, for example. We have long advocated—and still do—the eradication of barberry—the alternate host of the fungus. Long after it was recognized that the spores came in on the winds from Mexico, we continued to eradicate barberry because of its contribution to the sexual stage of the organism and hence the source of more new combinations. Now if you want to take the doomsday approach, you might also consider that this is the first time we have had such a major wave of this organism into these areas, and as I said before, this puts billions and billions of spores into the major corn belt.

You say that this was the first time?

Fulkerson: The first time that we have had a *major* wave.

Barnes: It's been up there before, but only to a minor degree.

Fulkerson: Yes, we picked it up in our corn plots right out here at Beltsville. So suddenly you get these billions of genetic entities throughout the corn-growing areas. And the mutation rate of these organisms is the same as the mutation rate of all forms of life—extremely low. Now when you increase dramatically the number of individuals, there is not only an opportunity for an increased chance for mutation in favor of greater virulence and pathogenicity, broadly speaking, but also an opportunity for development of individuals able to overwinter . . . to get along with other organisms . . . and their total ability to get along well with other corn plants—that is, new germ plasm as it is put into the system. Under these conditions, then, there is a greater potential for development of disease in race forms other than we have now. Now, admittedly, that is the doomsday side of the picture, but of course there are factors with which to balance that view. We know that when a population increases in a new area, the opportunities for new mutants that can get along in this area will also increase. Would you agree with that, Jack?

Barnes: Yes I would. We could cite other examples of this sort of thing.

I assume, then, that neither of you subscribes to this doomsday point of view. Are there other plant pathologists who do go along with this view?

Fulkerson: Yes, there are those who say that we will see more outbreaks in the form of other races.

Barnes: Particularly after reading E. C. Large's, *The Advance of the Fungi.* Pathologists who go back and read this book often intensify their feelings about the advances of fungal diseases.

Fulkerson: I might mention also that even after resistance was achieved in late blight of potatoes, new races came in that were more virulent than the early ones. To say that such a condition is upon us now is not consonant with the facts of the minute.

Barnes: We are confident that in the following months reason will take over as it did in other emergencies. Time has a way of bringing together more reason—as more facts come in. We have had other outbreaks and will continue to have them in a dynamic system.

Man, because he is working in a modern context of science, has no real reason to say that, because we are working in sophisticated times, we should disregard the annals describing worship of Rubigus or the migration from Ireland in the last century. We have seen epidemics before, and we have every reason to expect that we will have other epidemics in other forms or in other crops.

Fulkerson: Even without epidemics, which are a flamboyant example of nature out of balance, it is hard to be patient with the extreme ecological rhetoric about the *delicate* balance of nature. In a very real sense, biochemical evolution and the resulting behavioral aspects force one to sense that there has never been a delicate balance in nature—or in our ecology, broadly speaking. Man wants to view things this way because of the belief that, since God placed everything there, all the elements must be in a state of balance. Ecology capitalizes on this outlook on life.

But rather than a delicate balance, a case can be made that it's an absolute nightmare to the creatures of, say, Monterey Bay. When man looks at this scene, he enjoys seeing the gulls and seals in their so-called balance. If you go to a quiet pond someplace at night to fish, you may hear a raccoon catch a big bull frog on the shore. When you hear that frog scream, you know there is no delicate balance of nature; it's a terrifying war at all times!

This is an age-old conflict. But it ought to be recognized that, in one sense, this concept of a delicate balance of nature is almost a complete denial of biochemical evolution.

I believe we will always have these situations that plague man—such as plant epidemics. This does not mean we cannot cope with them. In fact there are better ways of coping with these situations than we've done in the past.

Barnes: We say smugly that we have learned our lessons from the pages of history—the potato blight, the chestnut blight, and others—and I wonder if we really have. Race T of the southern corn leaf blight fungus was discovered in the Philippines in 1963. In hindsight, should we have launched meaningful efforts to evaluate the potential of transporting southern corn leaf blight into the major corn-growing areas of the world? Did it arise *de novo* in the United States? Is there something out of balance in our views of the dynamics of today's world? But—if we accept the idea that southern corn leaf blight did move from the Philippines—or from the Caribbean—then we did not do a very good job of restricting its movement.

Fulkerson: Whether something is a epidemic or not depends upon where you stand. Consider, for instance, the two fine old elm trees in the front of our administration building—each a part of microecosystems. The one on the east side of the entrance appears to be quite healthy; it is one of the finest specimens in Washington. Yet the other one on the west side of the entrance shading Secretary Hardin's windows is now showing signs of disease. So in this case it depends on which window you are looking out of—what your viewpoint is—as to whether you think we have an elm blight epidemic.

I admit this analogy is a little crude. But if you're not really looking closely at changes in plant life, it is difficult to recognize that things have reached epidemic proportions for certain segments of the living complex.

The truth of the matter is, of course, that we *do* have an elm disease epidemic in the United States. It is moving across the country at about 100 miles a year and now is as far West as Wyoming. When you look at the situation in that context, it is really quite an epidemic.

Barnes: I remember a statement made and published in 1940 in which the author said: "Now that

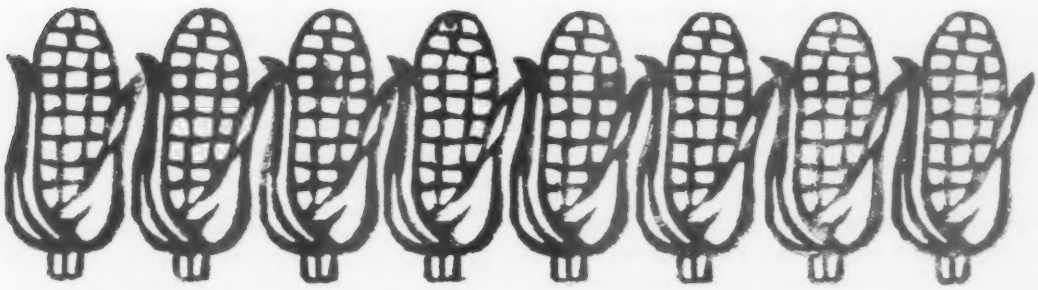
we have Dutch elm disease under control . . . ." He said this from the standpoint of what was being done at that time. And yet today we are still in a struggle with Dutch elm disease. But are we fighting for all we're worth? The answer obviously is no. Other problems seem to have higher priority, and this seems justified, in view of current national problems challenging agriculture. But, I submit that we must give greater attention to the better maintenance of *overall* balance.

Fulkerson: One point that needs mentioning here is that the total resources—manpower, time, and money—that have been applied to the Dutch elm disease problem are quite small compared to the magnitude of the problem itself. Of course we tend to concentrate our efforts where we think they are needed the most. In comparable areas of research involving humans and animals, much more massive efforts are directed toward solving the problems at hand. For example, there are more bacteriologists on the staffs of one or two large clinics in this country than there are plant bacteriologists in the entire United States. The point of all this is that, although research is continuing on Dutch elm disease, the effort is modest. Where man is more directly involved, the research priorities are naturally higher.

Barnes: In view of the amount of effort devoted to a given class of plant diseases, we need to give more consideration to the broad sweep of the total disease picture. This may seem an almost untenable requirement in terms of resources in which to set up this kind of program. I say this because it's quite possible that any year now we may have a major outbreak of a rust in wheat. We're heading that way; it's been 14 or 15 years since we battled race 15B, and we have every reason to believe that the fungus is mutating and recombining virulence factors. So in spite of what modern man has done with wheat—with his smugness about short-strawed wheat in Mexico, his smugness about how IR–8 is going to revolutionize Southeast Asia, we had best use more vision in terms of our concern about epidemics in these monocultured crops. As John says, the fungus is going through its biochemical evolution—this is inevitable. Therefore we have to look for a rationale or more balance in our research programs. We can't overdo things in any one area . . . and we do have a tendency to jump on "band wagon" programs . . . this is not always desirable.

Do you think that we are going to continue to rely on the T-type cytoplasm?

Barnes: First let me say that they will not throw out the T. We know so little about the cytoplasmic backgrounds as they interact with genes. The Ht gene for northern leaf-blight resistance in corn is a good example, and the T-gene in the fungus is another. I think we have enough evidence that the genes for southern corn leaf blight resistance (the evidence points to polygenic factors) behave in one kind of cytoplasm differently than they do in another. We will see more emphasis given to a search for other types of cytoplasmic male sterility—perhaps "analogs" of the C and S sources that I mentioned before, even though they are relatively hard to work with. Their "potency" is poorer than that of T. I think we will see further studies of these sources, and there will be further and further delimitations of subsources within these major



groups—the T-, S-, N-, and C-cytoplasms.

There are those who report that they can take the Ht gene and put it in a susceptible cytoplasm and the resultant plant isn't any more resistant than before. So we have incongruity between so-called single locus vertical resistance and the impact of a susceptible background. How much physiological impact does a bundle of RNA and DNA have on the ability to change the metabolism of that corn plant and the resultant expression of resistance?

Fulkerson: Yet, could you come down in the T-background for a dose of, say, 25 percent and still have quite a high level of resistance still in the T-complex? There is good evidence from breeders and geneticists that there is a real potential here to capitilize on.

Barnes: There will be those who will be working for a compromise—looking for the broader type of resistance. There will be those who will be doing other research on other loci, other genes for this specific resistance. This is healthy. We have to have these different approaches because they have shown such a benefit to the advance of science. We have contrasting philosophies working together and against each other.

Fulkerson: I agree that the T-strain will continue to be useful. In the end, it may well turn out to be one of our very best sources. This T-type, you see, is deeply buried in the industry. They can't afford to get back to detasseling.

Barnes: I believe that research on the fungus—and fungi in general—will intensify. The field of phytobacteriology is a good example. We know so little about the genetics of virulence in bacteria, and yet this is the key, I feel, to the halting progress we have made in combating fire blight, for example. Do we really understand the organism and its conjoiners in the environment, giving us the classic problems we have in fire blight? The same question is being asked today about the southern corn leaf blight fungus, *Helminthosporium maydis,* race T. Most phytopathologists, I believe, would say that we do not have this understanding—at least to the degree that we can adequately cope with disease situations as they arise. Therein lies our challenge.

Thank you, gentlemen.

A New Use for Whey

FOR years, cheese manufacturers and agricultural scientists have been trying to figure out what to do with liquid whey—a natural cheesemaking byproduct. Research has been directed both toward a profitable utilization of whey and a safe disposal of it as waste.

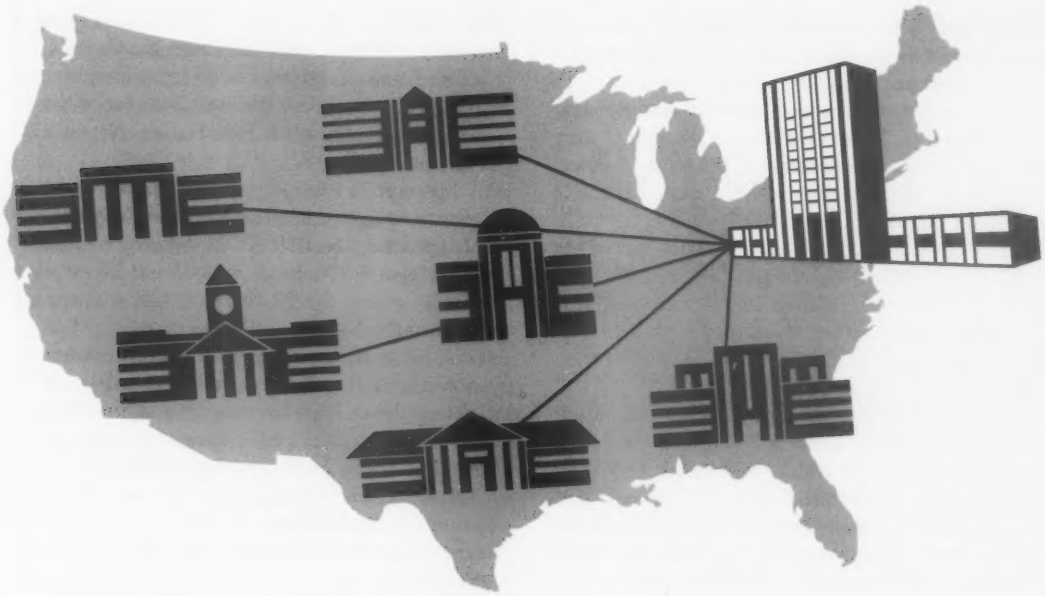
The problem of whey disposal is not as trivial as one might think. In 1966 alone, the United States produced 2.7 billion pounds of cheese. But in that same year, cheese manufacturers were left with 23 billion pounds of fluid sweet and acid whey. Much of this dairy byproduct is being diverted into streams or pumped into sewer systems, and according to today's standards of ecological practices it is regarded as an undesirable pollutant.

A new research development at the Wisconsin Agricultural Experiment Station, however, promises an exciting new use for whey. Food scientists G. O. Hustad, T. Richardson, and C. H. Amundson have found that dried sweet or acid whey can be made into a polyurethane type of foam.

Compared with most conventional polyether type foams, whey-based foam has inherent self-extinguishing flammable properties. It has a highly open-celled structure, low compressive strength, low density, and fairly good dimensional stability at temperature extremes. Moreover, it costs less to produce than other urethane foams.

Because whey foam can absorb shock, it has potential use in the packaging industry. It might also be used in building construction, because of its open-cell nature which should result in good acoustical properties. Above all, a market for this new product would provide another means of using whey to benefit the dairy industry.

Condensed from: *Science Report*
Bulletin No. 598, 1970
University of Wisconsin



AN INFORMATION NETWORK for the Agricultural Sciences

ELMER R. KIEHL

IN science, as in many other forms of human endeavor, specialization has become one of the hallmarks of professional respectability. A scientist may spend years working on one relatively small segment of the vast spectra of his discipline. Thus he could become an authority on, say, the antigenic property of cells or the metabolic fate of sterols.

This system has obviously wrought many benefits—not only through the advancement of knowledge in the particular discipline itself, but also by making new and improved technology available to society.

The system has, however, created certain problems among the disciplines themselves—notably a narrowing of interest that can hamper a broader understanding of related disciplines and an increasing difficulty in the sharing of knowledge.

It has been said that this new pattern in the world of science has fostered professional competition among the disciplines and the scientists, which in turn has prevented effective teamwork in areas requiring the talents and skills of many people. Scientists cannot, it has been said, easily bury a set of attitudes and mores for close-working partnership in problem solving. But I believe that this diagnosis is partly in error.

The Communications Gap

THE real problem lies not in professional competition, nor in lack of interest or understanding, nor in unique attitudes. Instead, I believe that our highly specialized scientific process has somehow failed to develop the art of communication to the degree demanded by the mounting stockpile of

This article is based on a paper delivered by the author at the Agricultural Sciences Information Network Symposium held at Washington, D.C., Feb. 10–12, 1970.

knowledge. Thus, I feel that the reluctance of many scientists to move into interdisciplinary research programs could be highly correlated with a grossly inadequate procedure in science information utilization. If the interfaces of disciplines were more freely exposed and utilized, the research enterprise would undoubtedly reflect a more favorable climate of tangible productivity.

Dr. Vannevar Bush, when he was director of the Office of Scientific Research and Development, correctly analyzed the situation in 1945 and outlined procedures which he felt would ameliorate the difficulties that the science disciplines were even then beginning to encounter.

"The investigator," he said, "is staggered by the findings and conclusions of thousands of other workers—conclusions which he cannot find time to grasp, much less remember, as they appear. Yet specialization becomes increasingly necessary for progress, and the effort to bridge between disciplines is correspondingly superficial." [1]

Bush envisioned a microfile storage device, the size of a desk, into which one could insert 5,000 pages of material daily, but it would take 100 years to fill its repository. It would provide instant access to all his books, records, and communications. He called it MEMEX. Actually, what he had in mind was a forerunner of a modern information storage and retrieval communications system. Twenty years later he acknowledged that this dream could now be achieved, although he doubted that it would become a reality very soon because society tends to apply such technology first to other more exciting areas of human endeavor. This reference to Bush's approach brings emphasis on the individual scientist who in his own creative way must absorb and manipulate by logical processes the data he observes.

Few science administrators can escape the common complaints of staff that they face mounting problems of being able to "keep up-to-date." At the University of Missouri, faculty committees have suggested that library assistants be attached to each key research staff member or group. More recently, a faculty committee has wrestled with the broader issues of storage, flow, and transfer of scientific information.

This concern is understandable. In my own research experience—much of it in a team research effort—I recall the prodigious amount of required literature search in a number of related fields. Yet I know we must have missed much that was pertinent and relevant which would have extended our capabilities both individually and as a team. I recall too one of my graduate professors recounting the fact that Mendel's concepts and laws of genetics were lost for 35 years because his publication did not reach the attention of scientists who could understand and grasp the significance of his findings. Today—even as in my earlier days—time bears heavily on a research scientist; moreover, accessibility of data through the standard library systems cannot provide the precise associated elements needed for effectual literature search.

[1] Vannevar Bush, "As We May Think," *The Atlantic Monthly*, July 1945.

At its October 1970 meeting, the Agricultural Research Policy Advisory Committee (ARPAC) approved the establishment of the Agricultural Sciences Information Network Committee.

Purposes of this new policy committee are: (1) to review the information development plan produced by EDUCOM under a research grant from the National Agricultural Library; (2) to review the 22 recommendations proposed at the February 1970 symposium; (3) to consider feasibility of the plan and the recommendations, establish priorities, develop strategy, and organize resources as needed; (4) to examine and explore alternatives about relations of the plan to CRIS, EMIS, and other data banks; and (5) to explore potential relations between the plan and the evolving national information systems in other disciplines.

Cochairman of the new committee are N. P. Ralston, Associate Director, Science and Education, USDA, and Elmer R. Kiehl, dean, College of Agriculture, University of Missouri.

Support For Science

ANOTHER disturbing element is creeping into the picture and seems to be compounding the dif-

ficulties scientists face. I refer to the increasing level of public skepticism about the value and contribution of research and science to current problems. Federal and State legislative support for science is becoming more and more difficult to obtain.

In his 1969 letter to the American Association for the Advancement of Science,[2] H. Bentley Glass suggested five factors that must be overcome in order to regain better public understanding of the role of science in our society. Two of these are pertinent to the issues at hand.

1. *The sheer volume of scientific information without adequate codification and storage.* Even with computers providing rapid, permuted indexing, many scientists, Glass believes, depend mainly on word-of-mouth reports from "fellows of the invisible college" to know what is going on.

2. *The ever-increasing specialization required for a scientist to carry out successful investigations.* Glass aptly compared the situation to Francis Bacon's metaphor about pioneers who dig out mountains of new ore that keep accumulating because of an increasing shortage of smiths who might refine and hammer the ore into unifying theories.

Other national issues—primarily those that relate to the quality of our environment—have gained rank in the list of national priorities, and there seems to be little likelihood that the support of science will regain the status it once had unless science itself steps in and remedies the situation. Obviously, one of the things that science can do is to use its talent more effectively. I am convinced that one of the most promising components of such a program is the improvement of science information utilization. But I am also convinced that this program will be exceedingly complex and difficult to mount. This is the problem that led to the scheduling of an agricultural sciences information network symposium. The first definitive action step has already been taken: the completion of the EDUCOM [3] research report, *Agricultural Sciences Information Network Development Plan.* Very simply, it is a long-range plan for strengthening the communication and exchange of science information between and among the libraries of the land-grant institutions and the National Agricultural Library and within the agricultural research community.

The Network Concept

FORTUNATELY, for the agricultural science disciplines, the concept of an information network has been given previous attention and study. I refer to the report of the Joint Committee of the National Academy of Sciences—National Academy of Engineering titled, *Scientific and Technical Communications—A Pressing National Problem and Recommendations for Its Solution.*[4] The study was undertaken at the suggestion and with the support of the National Science Foundation. Few other reports delineate so thoroughly the vastness and complexity of this problem and the great amount of integrated effort and widespread understanding that will be required for its solution. Because of the many groups involved—both public and private and scientific associations and societies—a high degree of coordination and planning at the national level seems to be warranted. The EDUCOM report is compatible with the NAS–NAE report and provides an excellent base for formulating the science network at the working level.

One notable characteristic of the agricultural sciences—and one which is often missing in other disciplines—helps to bring the goal of establishing an information network closer to reality. I refer to the long history of productive relationship between the land-grant institutions and the U.S. Department of Agriculture. They have a common mission of conducting basic and applied research and rendering service to people. Over the years they have developed a relatively high degree of cooperation and communication. Another tie that binds this structure is the fact that substantial portions of the funds are administered through the U.S. Department of Agriculture, and many research and extension programs of the States are carried out cooperatively with the Department. Four regional associations help to further unify the cooperative aspect of research and extension activities. Surely, this favorable climate of cooperation will help measurably in our common efforts to establish an

[2] H. Bentley Glass, Letter from the AAAS President, *AAAS Bulletin*, Vol. 14, No. 3. 1969.

[3] EDUCOM—The Interuniversity Communications Council.

[4] SATCOM Report, Pub. No. 1707, National Academy of Sciences, Washington, D.C. 1969.

effective system for a useful interchange of agricultural science information.

Prior to the time when the USDA Library became the National Agricultural Library, the ties between it and the researchers and teachers of the land-grant institutions were the conventional, traditional ones. The services, which included bibliographic compilations, documentation research, and translation services, were extremely useful, but the problem of distance and the general lack of awareness among State researchers did not make these valuable resources an effective input into the whole system. Now, however, the move of the National Agricultural Library to Beltsville and the expansion of its facilities, open up a splendid opportunity for introducing new viable elements of service in information exchange to faculties.

To help achieve a workable and effective system, an extensive reevaluation of the purposes and procedures of the National Agricultural Library is now underway. One component of this reassessment is the support that NAL has given to the EDUCOM study. It appears, therefore, that we have reached the point where we can now move forward to obtain the national coordination needed in providing researchers and teachers the quantity and quality of science information service that they so desperately seek and require.

Related Systems and Subsystems

THE agricultural sciences might well consider the growing number of related systems and subsystems in other disciplines as signs of the times—the inevitable realization that traditional systems of information exchange function imperfectly in the modern context. It is reassuring, also, to note that these earlier systems made many false starts before they began to function as their planners had hoped for. The variety and kinds of services they offer span a broad area of human activity. The telephone, radio, and television networks have had a long and successful history in communications technology and performance. Today, networks spread across the Nation for such services as motel and airline reservations, criminal detection, medical information exchange and many others. Most of these networks include emission, conveyance, switching, and reception of information. The advent of high-speed printers, high-capacity transmission lines, and computers has greatly encouraged the development of these modern information exchange systems.

Critical in the development of network systems is the effort underway by many of the professional associations in the organizing, abstracting and storage of information. The Chemical Abstract Service has been working since 1959 toward the development of an integrated information system. One of the oldest in the field, its aim is "not the computerization of a manual publishing service, but the development of a comprehensive integrated information system . . . The goal of this work has been to eliminate redundant human intellectual and manipulative effort in processing information and at the same time to create a broader range of more responsive information services, only some of which will be the traditional publications." [5]

Keenan lists 14 other such services including Biological Abstracts, Engineering Index, Physics Abstracts, and others, all of which are important for the research personnel in agriculture. Still other professional associations and organizations are making plans for such services. Within the agricultural sciences, the Agricultural Economics Association is working with the NAL in developing an integrated information system for economics. Other systems—generally more restricted in scope—are beginning to emerge. At present, these services cover only a limited segment of agriculture. The high degree of coordination for the establishment of compatible services among the many agricultural professional associations would seem to require the active participation and support of the National Agricultural Library.

A few years ago the joint effort of the U.S. Department of Agriculture and the National Association of State Universities and Land-Grant Colleges (NASULGC) produced a rather comprehensive report, *A National Program of Research for Agriculture*.[6] This examination of the total U.S. agricultural research and its assessment of needs and priorities has become the basis for our program projections nationally as well as by the individual institutions. New areas of research, and new configu-

[5] Stella Keenan, "Abstracting and Indexing Services in Science and Technology." In: *4th Annual Review of Information Science and Technology*. 1969.

[6] Joint Report, U.S. Dept. of Agriculture and NASULGC. Washington, D.C. 1966.

rations of research effort were proposed. One element overlooked in that report, however, is the vital need of strengthening the research information communication over and beyond that traditionally implied. The potential implication for increased productivity, in the longer run, is certainly one that deserves the attention of research administrators not only in the land-grant colleges but in the U.S. Department of Agriculure as well. Parenthetically, the implementation of the Current Research Information Service (CRIS) is a small yet impressive beginning to assist in coordination of research programs.

Support For the Network

A KEYNOTE factor in the successful development of an effective agricultural sciences information network is the need for whole-hearted support of the scientists themselves. This need has been aptly summarized in the SATCOM report previously mentioned: (1) Economic factors and time pressures encourage a sharing rather than a duplication of information resources; (2) technological developments now permit the integration of diverse multi-media inputs which have the capacity to cope with the projected increases in volume; and (3) machine-readable forms of scientific and technical information vastly increase the availability of that information to a broader audience of users. Many agricultural scientists are already beginning to experience the benefits of the various subsystems now in operation, through savings in time and a broadening of their knowledge base—all of which can lead to higher quality research outputs.

Initially, of course, many deficiences must be overcome. Apparently, it is no longer necessary to ask whether networks can be built. They *are* technically feasible. The far more difficult questions are what kinds of networks are needed to fulfill the needs of the agricultural science community, and how should they be created. These questions and other related topics must be debated among the professional scientists, the informational science specialists, the librarians, and administrators of science program. And as they are debated, the needs of the generators and users of information must be kept prominently in the forefront so that a network system is adopted that has the capability to adapt to changes in user needs and to changes in communications technique.

The involvement of researchers and enlarging the awareness of others in this new approach entails some initial risks. Some will view the investment in new procedures as a negative impact on their own productivity. This is likely true in the short run. But in the longer run, this approach promises to yield greatly enhanced opportunities for the larger scientific community. Some of the needs and desires of the user undoubtedly have been reflected in the configuration of the plan since a NASULGC Advisory Committee was appointed for this purpose.

It must be recognized also that, in the agricultural sciences, we have the unique problem of interfacing the languages of biological sciences, physical and engineering sciences, and social sciences. All of these must operate within the framework of agricultural science research. Such a form of communication will not be easy. Yet the tradition of cooperative relationship between the U.S. Department of Agriculture and the land-grant institutions should offer much encouragement to proceed and carry out the mission.

Changing Patterns In Beef Cattle Production

H. J. HODGSON AND R. E. HODGSON

THE beef cattle industry has not experienced the revolutionary changes that have characterized other segments of agriculture such as the production of certain crops—notably hybrid corn—and the highly efficient broiler industry. True, reproduction rate has improved slightly, beef cattle breeding is somewhat more efficient, and feedlot feeding has increased markedly. But the chief factor contributing to the dramatic increase in beef production during the past 15 years has been horizontal expansion—increasing the beef cow population. Although additional reasonable gains may be expected in such expansion, there are considerably greater opportunities for increasing beef output through vertical expansion—increasing the output per production unit. Vertical expansion also provides the potential for increasing efficiency of production along with higher volume. A number of methods for improving cow-calf management systems and overall herd efficiency show much promise.

The authors gratefully acknowledge the constructive assistance, through discussion and review of the manuscript, of E. J. Warwick and P. A. Putnam,, Agricultural Research Service, U.S. Dept. of Agriculture.

PRESENT STATUS

MOST cow-calf management systems have remained essentially unchanged for many years. A cow theoretically produces one calf a year (actual calf crop is 80 percent since 20 percent of the cows now fail to produce a calf in any one year); calving on range or pasture is associated with either

favorable feed supply or favorable weather. The cow and calf remain on pasture for 6 to 8 months after which the calf is weaned at 400 to 500 pounds. During this period the cow and calf compete for grazing, and in many operations cows consume more feed than might be profitable. Furthermore, if the quality of the grazing is sufficient for good growth of the calf, it is better than the cow requires. The cow is wintered, often losing much of the summer weight gain. At weaning, the calf is wintered and then pastured for a summer before fattening, or is placed on a limited grain-forage regime for a further growth period before fattening, or in some cases goes directly to the feedlot. The cost of maintaining the cow limits to a significant degree the profitability of the cow-calf operation. The 20 percent (7–8 million) of "dry" cows materially increases the total herd maintenance cost and reduces profitability significantly.

Considering annual liveweight production and number of beef cows 2 years old and over, and assuming that 15 percent of the total liveweight production of beef comes from dairy animals, we can calculate that in 1968 beef cow liveweight production averaged 876 pounds. Assuming a 55 percent dressing percentage, only 482 pounds of dressed beef are produced per beef cow. This points up clearly the need and the opportunity to increase the efficiency of production of beef.

Beef is a food with high consumer preference, as indicated by increases in per-capita consumption from 72 pounds in 1948–50 to 110 pounds in 1966–68. This factor, together with population growth, contributed to an increase in domestic production from 10.6 billion pounds in 1948–50 to 21.0 billion pounds in 1966–68. Prices paid to farmers for finished beef have remained essentially constant during that period while marketing costs have risen sharply.

Most estimates call for another doubling of demand for beef by the year 2000 and some authorities estimate that level could be reached sooner. The rate of increased demand will be greatly affected by price in relation to availability and price of substitutes such as meat analogues made from vegetable protein. Supplies of vegetable protein presently available from oilseed crops and potentially available from leaf proteins appear adequate to produce large quantities of protein-rich food. The technology of production is improving rapidly, and these products could become strong competitors of beef. The competition intensity will be determined largely by comparative prices. Therefore, significant economies in the production of beef are needed to meet this potential competition as well as that from imported beef. There seems little doubt, however, that beef has a bright future if economies and efficiencies can be achieved in production and marketing.

SOURCES OF IMPROVED EFFICIENCY

IN discussing the effects of several areas of improvement in efficiency of beef production, Warwick [1] assigned values to hypothetical levels of gain. Increasing the reproduction rate can reduce cost of production most (5.2¢ per pound); increasing efficiency of post-weaning gain (growth rate) and reducing excess fat each had about half that effect. These noteworthy objectives can, of course, be partially achieved by application of improved breeding, feeding, management, and disease control techniques already largely available. Crossbreeding and artificial insemination could be utilized more extensively to provide additional significant gains in efficiency. But to bring the beef cattle industry up to the level of efficiency and sophisticated management which it needs and deserves, even more revolutionary techniques will be required. Some of the newer avenues of research now being explored may provide the means to achieve this goal. These include induced twinning, complete control of estrus, and control of sex.

Crossbreeding

THE use of crossbreeding in commercial beef herds is increasing at a rapid rate, and at present about 30 percent of market cattle are crossbred to some degree. Significant gains in efficiency have resulted and more should follow as the practice becomes even more widespread. The trend is based on sound research that indicates up to 20 percent improvement over pure line breeding is possible through increased livability and growth response of

[1] E. J. Warwick, *Beef for Tomorrow*, Proceedings, 10th Annual Meeting, Agr. Res. Inst. Oct. 14–15, 1969, Washington, D.C.

the calf and increased feed-use efficiency. An increase in the use of certain dairy breeds in crossbreeding programs seems probable.

One of the deterrents to crossbreeding has been the solid standing of and favorable attitudes toward breed structure in beef and dairy cattle. In poultry, reliance on breed structure has almost completely disappeared, and the same situation is now beginning to take place in swine and sheep. As in other changing patterns in the beef cattle industry, crossbreeding is expected to be more universally practiced in the near future.

Artificial Insemination

ABOUT 2 percent of the beef cows in the United States were artificially inseminated in 1967. The trend is expected to follow that set in the dairy industry, and the practice promises parallel gains in efficiency of production. Accompanying artificial insemination (AI) are wider use of performance tested bulls and increased latitude to effective crossbreeding programs. Finally, it reduces the number of bulls required and thus provides some added measure of efficiency. There were 1.9 million beef bulls on farms in 1968 and a ratio of cows 2 years of age and older to bulls of about 20 to 1.

Through an AI program, a single bull—chosen for his past performance record—may sire as many as 50,000 calves in a year. This practice does not, however, make use of top-rated females. Currently, the only way this is possible is by means of ova transplantation—implanting fertilized eggs from the true mother in another female. Although it has been done experimentally with sheep, the present technique requires surgery, and is not very practical.

Induced Twinning

THE principle of multiple birth (twinning) promises to have more far-reaching effects on beef cattle production than any other science-based achievement to date. Although this technology is not yet available, intensive research now under way looks encouraging. Some difficulties have been experienced but there is a high probability that twinning could be a commonly used practice by 1980 if needed research inputs are provided. It is of such importance that increased research input should demand the highest priority available in animal science research. Furthermore, research in reproductive physiology in beef cattle would undoubtedly produce desirable spinoffs to other segments of the livestock industry and to our understanding of human reproductive physiology as well.

Since twinning and increased growth rates are complementary to other avenues for improving efficiency—crossbreeding, artificial insemination, control of sex, and control of estrus—the availability of technology for induced twinning may well be the key to bringing a number or all of these practices into general use. The economic impact of twinning would be such that the practice would probably receive widespread acceptance soon after it is available to cattlemen—perhaps within 5 years. Even if twinning technology is accepted on only a limited basis at the outset, its eventual adoption by more and more producers would cause a significant impact on the industry and at the same time bring about certain changes in cattle management systems.

Effects on Beef Industry—When induced twinning becomes a common practice, it is not unreasonable to expect calf crops of 160 percent or greater. Breeding in confinement associated with controlled estrus could well result in still higher birth rates. Thus, we would have the potential to double the number of slaughter animals within a short time. It is doubtful that the market could absorb such a rapid increase, because increases in per capita consumption of beef and population growth are of much lower orders of magnitude. Unless cow numbers were reduced accordingly, twinning would cause beef surpluses and subsequently reduced prices would be anticipated for slaughter cattle, feeder cattle, and calves.

An over-abundance of beef cows and consequently reduced prices would result in intense competition and cause elimination of operators with lowest efficiency in spite of reduced production costs from twinning. Similarly, areas of marginal production, such as many of the poorer range areas, would be unlikely to compete successfully. Accentuating the competition would be a doubling of the number of dairy animals available for beef if twinning is also applied to dairy cattle.

Significant adjustments would be expected also in the geographical distribution of beef cows; the most productive areas would probably hold a competitive advantage. At present about 57 percent of the beef cows are in the Plains States and the Corn

Belt States where large quantities of forage and feed grains are produced. An acceleration of the movement of beef cow populations away from extensive rangeland areas may be expected.

Effects on Management Systems—Most innovative methods for improving the efficiency of beef cattle production would be expected to require changes in the cattle management system. This would be particularly true if reduced twinning were adopted. Practices for improving efficiency can be aggregated in various ways depending upon economic parameters, cropping systems available, and managerial ability of the operator. New technology, particularly twinning, may generate demands for additional management information, but much of the information required for managing cattle with various combinations of technology is at hand or clearly indicated from prior research experience. Some changes in management systems might be along the lines indicated below.

Beef Cows—Twinning should be accompanied by early weaning of calves, because, obviously, milk production by the cow would be inadequate for twin calves for extended periods. If the cow herd consisted of animals of half dairy germ-plasm, the nursing period could be prolonged somewhat. But in any case it would seem highly probable that weaning would occur by the time the calf reached an age of 60 days and a weight of 150–175 pounds. Alternatively, calves could be weaned at a very early age—say, 1 to 2 weeks—as in the dairy industry. The advantage in such a practice is that the beef cow could be rebred and returned to maintenance rations sooner, thus reducing maintenance costs to a minimum. This, in effect, would shorten the calving interval to a year and possibly to 11 months. Weighed against this advantage, however, would be the added costs of special feeds, such as artificial milk, and increased labor costs for rearing very young animals.

Cows could be confined in lots or turned into calving pastures shortly before calving and fed stored feeds as required. This would permit the necessary close observation during the calving period. Controlled estrus would result in calving of most cows during a short interval, thus shortening the critical observation period. In addition, calves would automatically be age-classed to facilitate weaning, marketing, and other operations. At weaning, cows would be rebred and returned to mainte-

nance rations until shortly before calving again. Adequate rations could be furnished by utilizing large quantities of low quality feeds such as crop residues or even by heavy stocking on well-managed, high-yielding pastures.

Heavy stocking minimizes gain per animal but maximizes production per acre. Such techniques as fall-saved grazing and other forage management systems as outlined by Wedin [2] would be especially suited to low cost maintenance for beef cows. The use of urea in combination with low quality and inexpensive roughage offers much potential for low-cost maintenance of the beef cow. In addition to decreasing per-cow costs, such management has potential for increasing cow population per unit of land area. The central objectives are to maximize the reproductive rate of the cow to the practical limit, yet maintain her at the lowest possible cost. These two items—high reproductive rate and low cost maintenance—are two practices that bear heavily on high efficiency in beef production.

Beef Calves—The growth rate of the animal, affected both by inheritance and nutrition, is of paramount importance in increasing efficiency of beef production. Maximizing growth and fattening rates from birth to market age minimizes the proportion of feed consumed required for maintenance. For example, the total feed requirement for maintenance of an animal marketed at one year of age should be less than half that of an animal marketed at the same weight at two years of age. It follows that considerably less net energy would be required to reach a 1,000-pound weight in the shorter period (table 1). It requires higher quality and perhaps more costly feed to attain a given weight in a shorter period, yet considerable decreases in cost of production would accrue from savings on feed. In addition, interest on investment would be reduced if animals reached market weight at about 1 year of age instead of 18–24 months.

To achieve this sort of gain would require cattle with high genetically-determined growth potential and intensive production systems. Calves weaned at 60 days could be managed in two principle ways to achieve maximum growth rates. In areas of the country where very high quality pasture is available, grazing systems might be most economical. Supplemental feeding of concentrates on pasture would need to be provided as required. Regulation of stocking rate to achieve maximum gain per animal would be desirable. At the other extreme, calves could be kept in feedlots and fed stored feeds such as alfalfa haylage and corn silage. Or, a combination of these two systems might be most economical. The objective of maximum growth rate should prevail in either case so that animals would reach market weight of 1,000 pounds at an age of about 1 year. Animals under such feeding regimes would be growing continuously and might require only very limited full-grain feeding to finish them to choice grade. At any time during the growing

[2] W. F. Wedin, "What Can Iowa Do with 10 Million Acres of Forage?" *Iowa Farm Science*, Vol. 24, No. 9, 1970.

TABLE 1.—*Net energy requirements to produce a 450 kg (990 lb.) beef animal at various ages beginning at a weight of 100 kg at 65 days of age*

Age at 450 kg	Total Energy required	Relative Energy required
Months	*Mega-calories*	*Percent*
13	2800	100
17	3300	118
24	4300	154

Data calculated by P. A. Putnam.

period, animals could be sold to feedlots or marketed as lean, high quality beef.

Lot feeding of calves from weaning to slaughter necessarily requires considerable investment in equipment and feed storage and feeding facilities. This seems hardly feasible under present production systems. But technologies such as 160–200 percent calf crops, sex control, early weaning, and rapid growth rate bring a whole new set of economic parameters into play. Furthermore, harvesting and feeding systems allow utilization of higher production inputs to forages than do grazing systems. Thus it seems highly probable that a production system of lot feeding from weaning to slaughter would be feasible. Economic studies on various feedings systems and operation sizes seem warranted.

Twinning technology would provide the beef industry with capability to double the number of slaughter animals with no increase in cow populations. Systems of cow management similar to that described earlier should decrease per-cow maintenance costs considerably. These two items could reduce by more than 50 percent the per-calf cost attributed to maintenance of the dam. Capital costs such as land, building, investment, etc. also would be reduced on a per-animal basis. Finally, gains in efficiency from maximizing growth rates would be considerable.

A general meausre of the overall efficiency of the beef production industry is the extraction rate, the percent of the total beef cattle population slaughtered in any one year. Table 2 illustrates theoretical extraction rates from three systems of cattle management.

The theoretical extraction rate under the conventional system approximates our present-day status. Twinning with conventional management doubles output per cow but increases extraction rate only about 25 percent. Twinning plus intensive management doubles both output per cow and extraction rate.

Not all beef, of course, will be produced in intensive type operations in the future. There will still be opportunities where extensive operations will have economic advantage. This would be particularly true where extensive rangelands are commingled with areas of irrigation. Irrigated areas would be ideally suited to production of high yields of forage and grain crops necessary for the growing calf and extensive range areas would prove extremely economical for maintaining the cow herd between weaning and the next calving. It is not inconceivable that weaned 60-day-old calves could be shipped to areas of concentrated feed production. In that event, the better rangelands may be highly competitive for maintaining the beef herd. Furthermore, it appears that early weaning and separation of calves from the cow herd would provide for some needed operational latitude in devising range management systems more suitable to improvement of

TABLE 2.—*Theoretical extraction rates per 100 brood cows from three systems of cattle management.*

System	*Brood cows*	*Calves* [3]	*Yearlings*	*Extraction Rate* [4]
	Number	*Number*	*Number*	*Percent*
Single birth [1] (conventional)	100	80	80	31
Twinning and conventional	100	160	160	38
Twinning and intensive [2]	100	160	—	62

[1] Conventional system—calves weaned at 6–8 months of age and marketed at 18–24 months.
[2] Intensive system—calves weaned at 2 months or less and fed to market weight by 1 year of age.
[3] Assumes 80 percent of cows bred have single or multiple birth.
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the resource while maintaining high economic return.

Those responsible for allocation of resources for range research might well examine current and anticipated programs to determine relevance to expected shifts in the beef industry. Research emphasis on areas of lesser competitive potential probably should be oriented away from livestock production and toward other uses such as wildlife, recreation, watershed potential, etc. On the other hand, research for rangeland areas of greatest competitive advantage should be directed toward questions relevant to the anticipated changes in beef production. Furthermore, Federal agencies responsible for administration of large expanses of Federal lands should include such considerations in their long-range planning.

Control of Estrus Cycle

ANOTHER very promising method for improving the efficiency of beef cattle production is control of the estrus cycle so that conception rates would not only be higher but also timed more advantageously for the producer. Approximately 7 to 8 million beef cows in the United States annually fail to reproduce; the inherent loss to the industry in this irregularity is a sizeable one—both through lowered calf output and higher production costs resulting from the need for multiple services in breeding.

Of the known methods for altering the estrus cycle of the cow, the most promising one is to inhibit ovulation for a given period by means of a progestational steroid (hormone) administered either orally in the feed or by subcutaneous injection. Withdrawal or withholding of the hormone compound can then result in synchronized estrus.[3]

Although some advances have been made in the past 5 or 6 years, a fair amount of research is still being conducted in an effort to devise more practical and effective control methods. Some authorities believe that it is only a matter of time before estrus control will be rather widely practiced. Its advantages in conjunction with artificial insemination and induced twinning are recognized by many commercial beef cattlemen.

[3] Wm. Hansel, "Evaluation of Methods for Controlling the Estrous Cycle," In: *Proceedings, Conference on Estrous Cycle Control in Domestic Animals*, U.S. Dept. of Agr., MP No. 1005, 1965.

Control of Sex

CONTROL of sex, which may also be achieved by 1980, offers a considerable measure of increased efficiency in the beef cattle industry. At present, births in cattle are roughly half male and half female, but under some conditions it would be desirable to alter this proportion. For example, only cows from which replacement animals were desired would be bred to produce heifers. All others would produce bull calves. Bull calves are about 40 pounds heavier than heifers at weaning and about 10 percent more efficient in feed utilization.

Control of sex may be accomplished, in theory, by separating sperm into male and female components, and, by artificial insemination, impregnating either all male sperm components or all female, according to what is needed in the particular breeding program. Most of the current research on control of sex is now being done in the United States, although some has been done in England. One of the hindrances to this research has been the issue of moral and ethical matters, since—if it were possible in domesticated mammals—the process could probably be adapted for human use. However, as world demands for protein from meat sources increase, it is expected that these related problems will be overcome.

BROADER IMPLICATIONS

THE implications of anticipated innovations in beef production reach far beyond the industry itself. Cash receipts from cattle and calves totaled $11.3 billion in 1968—about 25 percent of all farm cash receipts. This figure, of course, reflects sizeable values of forages, feed grains, various byproducts and other farm products marketed through beef cattle. Furthermore, the industry generates a great deal of economic activity beyond the farm. It follows, therefore, that significant changes in an industry of this magnitude must have profound effects on the input industries and on the segments of the economy that handle and process the commodity after it leaves the farm.

Two of the more obvious aspects that will be affected will be feeding patterns and crop production patterns. Heavier demands on feed grains could materially affect reserve supplies. It is also conceivable that herd size could be affected, which in turn would have implications on our growing animal wastes problem.

Feeding and Cropping Patterns

DOUBLING the number of calves produced and fattened would increase materially the demand for forages and feed grains. Forages now provide nearly 75 percent of the feed units consumed by all beef cattle, and beef cows obtain about 95 percent of their feed units from forages.[4] Twinning and intensive calf management would decrease the percentage of beef cows in the total beef cattle population and thus tend to decrease the percent of total feed units supplied by forages. Total forage consumption would increase, however. Pasture would assume a lesser role and harvested and stored feeds a much greater role. Pasture, used principally either for beef cows or for beef calves, will require different grazing systems and perhaps different species for each use. Pasture and harvested forages for calves must be of the highest quality possible, while quantity probably is economically most important for cows.

Production of the estimated needed amounts of harvested forages and feed grains poses some significant problems that must be answered if we are to produce them without increasing, or even while decreasing, agriculture's contribution to pollution from soil erosion, wastes, pesticides, and increased fertilizer usage. Higher genetic yield potential of forages and feed grains, higher nutritional value of forages, and improved production, harvesting, storing, and feeding systems will be required. These will require additional inputs of critical and relevant research—both applied and basic. Some animal and crop production practices may become obsolete and along with them corrolary fractions of current research. New possibilities in livestock management imply new and different aggregations of production inputs of land, labor, and capital for which relative efficiencies are yet to be determined.

Intensive feeding of the increased number of calves resulting from twinning might nearly double the demand for feed grains. Increasing the demand

[4] H. J. Hodgson, "The Importance of Forages in Livestock Production in the United States". In: *Forage: Economics/Quality*, American Society of Agronomy Special Pub. No. 13, 1967.

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for feed grains so greatly over a rather short span of years probably would materially affect reserve supplies, probably eliminating them completely. These possibilities should be considered in long-range planning of farm policy and in activities of concerned agencies.

Herd Size and Related Factors

IN sections of the country where excellent pasture is not available throughout the growing season or where large quantities of corn and alfalfa may be grown, early weaning of calves likely would be followed by lot feeding of feeds like alfalfa haylage and corn silage. Corn silage is an excellent feed and harvesting the crop as silage maximizes yield of nutrients per acre. Similarly, high production inputs of forage on good land are more profitable with a harvesting and storing system, such as haylage, than with a grazing system. Silage and haylage are feeds that are not moved over sizeable distances as are feed grains. Furthermore, animals grown under such a feeding regime would require shorter fattening periods to achieve a given finish. All of these combined production practices may be sufficient to enable operators with farm-size herds to compete more equitably with operators of large-scale production and feeding operations. A likely spin-off factor would be a bolstering of the rural economy in certain areas. Economic studies for such production units appear warranted.

Increasing concern about the pollution potential of very large feed lots may result in legislation that will require costly adjustments in waste disposal practices. The capability of smaller, on-farm growing and fattening enterprises to dispose of animal wastes on farm land economically and with minimal pollution risk appears to offer additional competitive advantage. Furthermore, it may well be an essential key to safe disposal of beef animal wastes.

Many significant questions can and will be raised as the potential revolution in beef production is considered by specialists and administrators with differing backgrounds. It is important that these questions be raised and discussed now to provide a strong basis for farm policy planning, farm operations planning, and the necessary allocation of research resources.

The beef cattle industry may take other courses than those we have suggested. One thing, however, is certain: The research now underway and in the planning stage will produce new technologies that will have profound effects on a very large segment of the agricultural sector—and even on nonagricultural sectors of the American economy. We should be thinking about the effects of the application of this new technology and begin now to devise needed policy, action, and research programs.

Electrical Energy and Plants

A NEW publication issued by the Maryland Agricultural Experiment Station gives a comprehensive review of the little known field of electrophysiology of plants. Titled, "Influence of Electrical Energy on Plants: A Review," the bulletin discusses in well-organized fashion the principal findings in 107 different citations. The author is F. W. Wheaton of the Agricultural Engineering Department.

As author Wheaton points out, there has been a paucity of research on the influence of the electrical environment on the growth rates of plants. Although much of the earlier research has been directed toward measuring plant response to an electrically modified environment, later research has dealt with more sophisticated studies on the relationship between biolectric potentials and various plant functions.

Even though the literature citations in the Maryland bulletin date from well back in the 19th century, over a third of them carry dates in the 1960's, which presumably indicates a recent renewed interest in the field.

Two of the leading researchers in electrophysiology, E. J. Lund and L. E. Murr, have apparently come to the same conclusion that electrical energy affects growth through stimulation or disruption of oxidation-reduction or enzymatic reactions in respiration.

Poly-Unsaturated Milkfat:
A New Development From Australia

TREVOR W. SCOTT AND LEONARD J. COOK

THE content of poly-unsaturated fatty acids in ruminant milkfat is typically very low, despite the fact that the major fatty acids in pasture grass are linoleic and linolenic acids—two of the most common poly-unsaturated fatty acids found in nature.

Rumen processes are responsible for this conversion. During digestion, the poly-unsaturated fatty acids in the grass are released from their complex lipid structure and are converted to more saturated forms by the rumen micro-organisms. In effect, the "soft" (poly-unsaturated) fats are transformed into "hard" (saturated) fats by the normal biohydrogenation process characteristic of ruminant digestion (*4, 7, 9*).[1] Because of this hydrogenation process, it has hitherto been impossible to increase the proportion of poly-unsaturated fats in ruminant animals by feeding poly-unsaturated oils or by intraruminal infusion of these oils. Although previous studies have shown that this change can be accomplished by intravenous injection of oil emulsions (*8*), the procedure is unsatisfactory for use in dairy practice. Now, however, our CSIRO animal physiology and dairy research laboratories have developed a technique to protect poly-unsaturated fatty acids against microbial hydrogenation in the rumen. Such

[1] Italic numbers in parentheses refer to Literature Cited, p. 28.

protected fatty acids, when fed to lactating ruminants, are absorbed and appear in substantial amounts in milkfat (*6*).

The Technique

BASICALLY, the technique involves the production of a special dietary supplement consisting of small particles (15–50 microns), each of which contains poly-unsaturated oil droplets (0.1–2 microns) encapsulated by a layer of protein (fig. 1). The particles were obtained by spray-drying an homogenate containing equal parts by weight of linseed oil (50 percent 18:3; 19 percent 18:2 acids) and sodium caseinate. After being spray-dried, the particles were treated with formalin (37 percent formaldehyde) to protect the protein coating against microbial proteolysis in the rumen (*2*). This coating is insoluble in the neutral condition that exists in the rumen, but when the particles reach the acidic condition of the abomasum, the chemical link between formaldehyde and protein is broken—thereby enabling the poly-unsaturated oils to be digested and absorbed from the small intestine. Improved methods of formaldehyde treatment are currently being developed at the CSIRO laboratories; it seems highly probable that formaldehyde can be complexed with the protein prior to spray-drying.

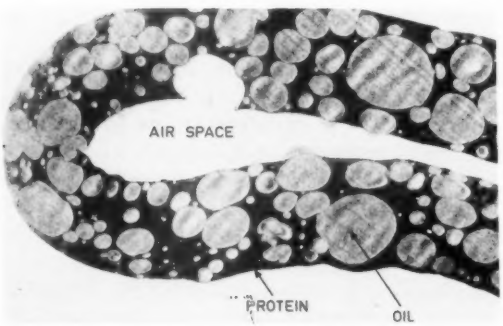

FIGURE 1.—Electron micrograph of safflower oil-casein particles (1:1 w/w) in cross section. Magnification X22,500. Particles were stained with osmium tetroxide. (Micrograph was prepared by R. Gemmell, C.S.I.R.O., Division of Animal Physiology, Prospect, N.S.W., Australia.)

In Vitro—In Vivo Experiments

RESULTS of the *in vitro* experiments, in which the linseed oil-protein particles—treated and untreated—were incubated with strained sheep rumen contents, showed that the formaldehyde-treated particles were completely protected from microbial hydrogenation. The proportions of C_{18} di- and triunsaturated fatty acids were the same before and after incubation of the treated material. In contrast, when untreated samples were incubated both linoleic (18:2) and linolenic (18:3) acids were substantially hydrogenated and there were corresponding increases in the proportions of monoenoic (18:1) and stearic (18:0) acids.

Experiments *in vivo* were undertaken to determine whether the formaldehyde-treated particles were resistant to hydrogenation and whether the unsaturated fatty acids were available for incorporation into milk lipid. Initially, two lactating goats were fed once daily a diet of chopped lucerne hay (1,000 g.), oat grain (1,000 g.) and untreated linseed oil-protein particles (500 g.). Goat 1 consumed 90 to 95 percent of the daily ration offered and goat 2 consumed approximately 60 percent. The diet was fed for four days and milk samples were taken prior to the initial feed and on the fourth day of the feeding regime. Two weeks later this experiment was repeated on the same goats using formaldehyde-treated linseed-oil protein particles. The dietary intakes of the goats were similar to that reported above. The fats were extracted from the milk by the procedure recommended by the Association of the Official Agricultural Chemists, and the fatty acid compositions were determined.

Upon extracting the fats from the milk, results showed that feeding of the formaldehyde-treated particles increased the proportion of linolenic acid (18:3) from 1–2 percent to 21–25 percent in the milkfat of both animals. On the other hand, the feeding of the untreated particles only increased the proportion of this acid from 1 percent to 4 percent. The increase in the proportion of C_{18} mono- and di-unsaturated fatty acids in the milk fats from the animals fed the untreated particles may reflect incomplete ruminal biohydrogenation of linolenic acid.

The failure to observe an increase in the proportion of stearic acid in milkfat from animals fed the untreated particles may be due to the desatura-

TABLE 1.—*Effect of feeding a diet containing formaldehyde-treated linseed oil-protein particles on the fatty acid composition of cow's milk*

Fatty acid	Cow 1		Cow 2	
	Control	Experimental	Control	Experimental
	Percent	*Percent*	*Percent*	*Percent*
14:0	16.7	10.6	13.5	10.5
16:0	33.4	19.3	31.6	17.9
18:0	9.4	12.8	10.3	6.1
18:1	25.0	30.7	29.5	25.9
18:2	1.4	5.7	1.5	9.5
18:3	0.8	12.3	1.1	21.9

Values are expressed as a percent by weight of the total fatty acids.

tion of stearic acid to oleic acid in the mammary gland (*3*).

Lactating dairy cows were then fed a diet containing the formaldehyde-treated linseed oil-protein particles. As with the goats, there were significant increases in the proportions of linolenic (18:3) and linoleic (18:2) acids in the milkfat, and the data are summarized in table 1. Control animals were fed a diet containing chopped lucerne hay (5,500 g.) and oats (3,500 g.). Experimental animals were fed for two days on the same diet plus a supplement of linseed oil-protein particles (1,500 g.). Cow 1 consumed approximately two-thirds and cow 2 consumed all of the ration offered. Each cow produced approximately 7 litres of milk per day.

When safflower oil-casein supplements were fed to 8–10 week old lambs there were significant increases in the proportion of linoleic acid in perinephric, mesenteric, and subcutaneous fat. After 3 weeks of feeding, the poly-unsaturated fatty acid content of perinephric fat increased from 4–5 percent to approximately 15–20 percent (*1*). Comparable experiments with cattle have produced similar changes in proportions of poly-unsaturated fatty acids in the adipose tissue and muscular fat (*5*).

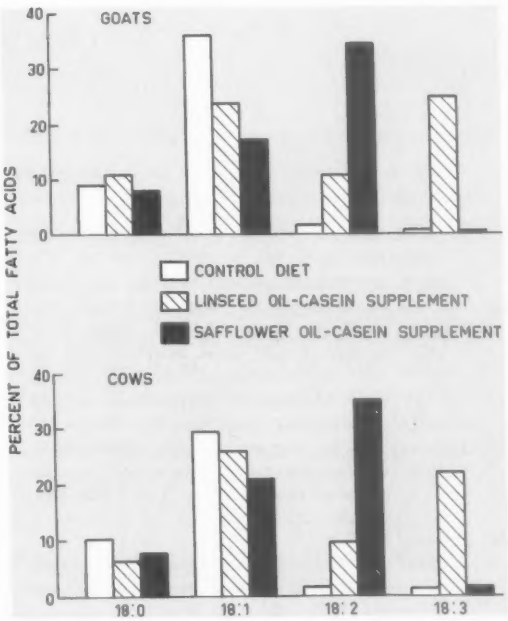

FIGURE 2.—Effect of feeding protected oil-casein supplement on the C^{18} fatty-acid composition of milk from cows and goats.

Prospects and Problems

THE amount of poly-unsaturation obtained in the milkfat depends on the level of feeding; furthermore, the nature of the fatty acid incorporated into the milkfat can be altered by changing the type of oil used to prepare the dietary supplement (fig. 2). Poly-unsaturated vegetable oils that may be used include soybean, safflower, sunflower, corn, linseed, and peanut. Some vegetable oils such as coconut and olive oil which contain low amounts of poly-unsaturated fatty acids cannot be used. It should be noted that the use of oils with undesirable flavors, for example, linseed, will result in these flavors appearing in the milk. In the studies to date only casein has been used to encapsulate the oils, but the possibility exists that other soluble protein—gluten, gelatin, etc.—may also prove suitable.

Much remains to be learned about the physical and chemical properties of dairy products that contain varying degrees of poly-unsaturation. To this end, collaborative research is being conducted with the CSIRO Division of Dairy Research. One phase of this research will include studies on the production of harder butters which have special uses for the baking industry, in the tropics, and by the armed services. This quality might be obtained by feeding supplements containing saturated fats—or by inhibiting certain enzymes that convert some of the saturated acids to mono-saturated forms in the mammary gland. Further studies will be conducted on the protection of other desirable fat soluble substances that would normally be degraded in the rumen—antioxidants, vitamins, hormones, and flavoring substances.

A full evaluation of the process cannot be made until more biological and technological information is obtained. Furthermore, long-term feeding trials will be necessary to examine the effects on animal health and productivity.

From the medical or human health viewpoint, the availability of poly-unsaturated ruminant meats and dairy products should provide more suitable diets for those persons suffering from cardiovascular disorders. It also seems probable that medical research workers would find some usefulness for such fats in their studies on the pathogenesis of atherosclerosis.

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The American Tung Nut Industry

W. WILSON KILBY

A dispassionate observer in the early 1970's might very well take a dim view of the economic outlook for the tung industry in the United States. Beset on the one hand by decreased usage, declining prices, and competition from a cheaper import product, U.S. tung growers saw many of their orchards battered to destruction by Hurricane Camille in August 1969.

But even after enduring such economic and physical stresses, there are signs that the industry is refusing to succumb to the forces working against it. One of these signs—and certainly not one to be taken lightly—is the faith that men like the author of this article have in the future of the tung enterprise. There are other signs too, of course, and author Kilby, who has devoted nearly an entire lifetime to the study of tung, identifies them as he weaves a fascinating story about the history, the progress, and the problems of this small segment of American agriculture working with a product that for centuries was known only to the Orient.—Ed.

LIKE many other American agricultural crops, the tung nut tree [1] traces its origin to the Old World. Its introduction in the United States, however, was rather recent—1904. Seedlings were first grown by the U.S. Department of Agriculture at Chico, Calif., and later were distributed to other areas to test their adaptability and potential as a U.S. crop. The trees grew well and seemed best

[1] The commercial tung tree grown in the United States is in the genus *Aleurites* of the *Euphorbiaceae*, or Spurge, family. The species grown commercially in the United States is *fordii*. There are four other known species: *montana, cordata, trisperma,* and *moluccana*. The *montana* species is grown only in southern China and Africa for production of oil.

adapted to the southeastern states. Eight years later—in 1912—the Bureau of Plant Industry issued a special bulletin, carrying the personal approval of Secretary of Agriculture James Wilson, which urged growers to set out tung orchards and at the same time offered a limited number of free 1-year-old trees to those who had serious intentions. The idea caught on—although rather slowly at first—and by the late 1920's it was apparent that the Gulf Coast States had a new agricultural industry.

History and Uses of Tung Oil

THE tung-oil tree is indigenous to China, where seedlings have been planted for centuries on the heavy-clay hillsides and waste places along the Yangtze River above Hankow—roughly between the 22d and 32d parallels of latitude. Oil expressed from the fruit, or nuts, of the tung tree has been used for hundreds of years by the Chinese as a waterproofing material for wood, cloth, paper, and other porous materials. The first known record of the use of tung oil in paints occurs in the "Book of Poetry," compiled by Confucius more than 24 centuries ago. Its superior qualities as a protective coating for wood resulted in its being called China wood oil.

The first known shipments of tung oil to Europe were made in the 13th century by the Portugese. It was not until 1869, however, that the first shipment came to the United States. But because U.S. technologists disagreed as to the value of tung oil as an ingredient for varnish, its use was extremely minimal until shortly after the turn of the century. Between 1912 and 1919, imports averaged about 43 million pounds a year. Thereafter they climbed steadily until more than 174 million pounds of oil was shipped to this country in 1937. Since then, imports have fluctuated widely because of the Sino-Japanese War, World War II, and an embargo on imports from Communist China.

After the outbreak of World War II, it became impossible to obtain shipments of tung oil from our principal source, China. Since some products vital to the war effort contained tung oil, its use was restricted by the Government, and the supply then on hand was placed under allocation. This action was a great incentive to the development of the tung-oil industry in this country, which was then in the fledgling stage. As history will show, however, the actions and policies governing the use of tung oil at that time led directly to its decreasing use during and after the war. Both public and private research chemists were put to the task of developing acceptable substitutes. This effort was accomplished to the extent that by 1957 domestic consumption was down to 45 million pounds of oil, and in 1969 only about 32 million pounds was used by U.S. industries.

Other factors, of course, were responsible for the decline in the use of tung oil, in addition to the loss of the import source and the development of substitutes made from other natural oils and synthetics. Lack of interest of the individual end-user for a high quality product and mass construction of housing developments where floors and wall materials are precoated with inexpensive finishes also were contributing factors. In addition, shipments of tung oil to this country prior to World War II were often adulterated with cheaper products by foreign exporters to increase their profits. All of these factors led, naturally, to the development of substitutes and greater emphasis being placed on expanding the production of domestic tung nuts.

During the years of peak consumption of tung oil in the United States, it had become an important raw material in the protective coating industry and by special-use industries engaged in manufacturing hardwood board, auto brake linings, linoleum, oilcloth, printing inks, gaskets, adhesives, composition moldings, caulking compounds, and insulation for electric wires and equipment. In fact, this growing diversification in the use of tung oil prompted some early authorities to predict that domestic consumption would eventually require the planting of 400,000 acres of tung orchards.

Although this forecast never become a reality, it appears that we have, in the United States, a sustained number of hard-core users who continue to rely on tung oil, since annual consumption has remained at around 32 million pounds of oil for the past decade.

Development of the American Industry

WHEN the first commercial tung orchards were planted in Florida by the American Tung Oil Corporation in the mid 1920's, no information was available on the cultural requirements of the crop. By 1930, nearly 8,000 acres of orchards had been

planted in Florida, and extensive plantings were made in Louisiana, Mississippi, and to a smaller extent in Alabama, Georgia, and Texas. By 1938 about 200,000 acres were in commercial orchards. During the 1950's and onward, more tung oil was produced in Mississippi than in any other State. The largest crop ever produced in the United States was in 1958 when 44.5 million pounds of oil was milled.

By the 1930's, domestic tung nut production had progressed to the point that it was apparent tung could become an important cash crop in the Gulf Coast States. However, there was very little published information on cultural requirements, climatic and soil limitations, and varieties. Thus the most basic growth requirements had to be established before there was any hope for expanding the industry to be economically successful.

THE TUNG TREE

The tung is a deciduous tree that grows rapidly to a height of 40 feet at maturity. Its leaves are broad, dark green, and heart-shaped. The shape of the leaf gave the tree its name, tung *being a Chinese word for* heart. *Tung fruits are about the size of small apples and are borne in clusters. They mature and drop to the ground in late September to early November. Each fruit contains 4 or 5 seeds, or nuts, which resemble a Brazil nut, although slightly smaller. Nut meat is white and oily, and cannot be used for food. Tung nuts contain about 20 percent oil when dried for processing.*

Tung trees usually begin to bear fruit in the third year and are in commercial production by the fourth or fifth year, attaining full production by the 10th to 12th year. The average life of a tung tree is about 30 years. Under favorable climatic and cultural conditions, an acre of tung trees will produce about 2 tons of fruit.

Research Programs

SEEING the need for useful research information, State experiment stations in Louisiana, Mississippi, and Florida began setting up experiments in the 1920's and 1930's. However, the paucity of reliable information on tung growing led the U.S. Department of Agriculture to begin an extensive research program on tung production in 1938. Field laboratories were established from Louisiana to Florida; the program was conducted in some areas in cooperation with State experiment stations, and particularly with the Mississippi Station. At Gainesville, Fla., a USDA field laboratory for tung investigations was established and staffed with the major plant and soil science disciplines. At Cairo, Ga., a laboratory was constructed and staffed for field experimentation that was conducted in southern Georgia and western Florida. A one-man field station was operated at Fairhope, Ala., and later moved to Mobile, Ala., to serve the research needs in extreme western Florida and southern Alabama. The main research laboratory for these investigations by the USDA was based at Bogalusa, La. Ten miles east of Bogalusa in the extreme southeastern part of Mississippi, a 440-acre tung research farm was established cooperatively by the USDA and the Mississippi Agricultural Experiment Station.

As the economical feasibility of the production shifted from the deep-sandy soils of eastern Florida to western Florida, southern Mississippi, and eastern Louisiana where soils were better adapted, the research laboratories of both the USDA and State experiment stations altered their efforts. Today, the USDA maintains tung research laboratories at the Big Bend Horticultural Laboratory, Monticello, Fla., and the South Mississippi Branch Experiment Station, Poplarville, Miss. Both of these States have cooperative research programs with the Department of Agriculture at these locations.

When tung was first planted in southern United States and produced under cultural practices similar to those used in China, the yields were low and unprofitable. Thus, the first research was necessarily of a practical nature to determine soil-type adaptability, fertilization and cultivation practices, climatic ranges, and the development of improved varieties. Large-scale field experiments were conducted with exacting design so that precise information on many variable factors could be statistically analyzed for effect of a treatment and interactions between them.

Soils—All types of soil were tested for adaptability. Early growers, anxious to plant rather extensive acreage, often planted without regard for soil types, which, along the Gulf Coast, are extremely variable from deep sand to an impervious clay. Thus, conditions were available to research workers to study the growth and development of the trees on a wide range of soil types and topography. Information was developed from these experiments which has been invaluable to growers in selecting orchard sites. Tung is very sensitive to poor internal drainage, but its needs for adequate moisture require that the soil also have a good water storage capacity. An ideal tung soil has been described as one having a sandy loam or loamy sand surface, underlaid at 12 to 24 inches with a friable sandy clay, through which water will percolate readily and which tung roots can penetrate easily but can store moisture for use of the trees during dry weather.

Fertilization—Most of the soils along the Gulf Coast are inherently low in fertility. That profitable crops could not be produced without liberal amounts of fertilizer applied annually was evident from the beginning of the first commercial plantings. Moreover, the needs of the tree for chemical fertilization change with age and production. Young trees respond to nitrogen and phosphorus and, where a deficiency occurs, to zinc and certain other minor elements. As the tree matures with a deeper root system and begins to produce a crop, the ratio of elemental fertilizer should be changed. Since tung bears from the terminal bud, the number and length of terminals determine the number of fruit produced per tree. Nitrogen greatly influences this growth along with adequate amounts of phosphorous. As the tree produces crops, potassium is taken from the soil at the rate of 30 pounds per 1 ton of whole fruit. Thus, if adequate fertilizer is not applied, the land cannot be cropped long before a potassium deficiency could occur. Potassium greatly influences the filling of the nut and thus the oil content of the crop.

This type of information, along with the requirements of certain minor elements in a given soil area, has been developed by extensive field experiments throughout the tung-growing area. In the course of conducting these experiments, leaf samples were analyzed, and a critical range of leaf content of each element involved in the fertilizer program was established. Thus, a grower can take leaf samples and prescribe in a more intelligent manner his orchard requirements for the coming year. This practice is now being adopted in other plant fields.

Through this cooperative research effort of the USDA, State experiment stations, and cooperating growers, it is possible for the tung grower to know precisely what his fertilizer needs will be for the most economical return from his crop.

Cultivation—At the beginning of the tung industry in the United States, it was thought that the crop could be grown much like it is in China, that is, no fertilization or cultivation being required. However, this grove-type minimal care plant was unproductive, and it soon became evident that this type of production could not justify or support land use in this country.

Carefully planned and designed experiments were conducted to evaluate methods of cultivation and orchard management. Tung trees will not grow in competition with grass. The grass not only competes for nutrients and moisture, but there seems to be a restricting biotic effect, which has been proved in carefully controlled experiments. It immediately became evident that clean-cultivation of newly planted and young trees would be absolutely necessary to obtain satisfactory growth and development. As the trees become older, deeper rooted, and partially shade the ground, less intensive cultivation is required.

When the mechanical harvester was developed, a special type of cultivation was necessary to accommodate the machine. The land surface must be left clean and smooth but not necessarily level in the last cultivation of the summer. Recommendations are now made for this operation, but additional research needs to be conducted on this problem.

Varieties—Tung was introduced into this country as a relatively unselected seed-propagated species. No varieties had been developed in China. By the time a full-scale research program was begun, there were several thousands acres of tung trees growing in commercial orchards. These trees were heterozygous, which, when propagated from seed, segregated unlike progenies.

An extensive selection and breeding program was conducted. The objectives at that time were to find outstanding individual trees with a history of high annual production, high oil content of the fruit, and

good conformation of the tree. Commercial orchards were scouted from Florida to Texas. When trees were selected, a collection of seed and budwood was obtained. These trees were then propagated and their progenies planted in hundreds of acres of test orchards owned by cooperating growers. From literally hundreds of these selections, only six were ever named as varieties and released to the public. These varieties were capable of producing seedlings that would be from 75 to 90 percent uniform and genetically true-to-type of the mother tree. This development was an important factor to the fast growing industry. Nurseries could be planted and seedling trees produced in one year. In some cases, seed was planted in the actual site for the establishment of an orchard. However, this practice proved successful only where newly cleared land was available for the orchard site; otherwise, grass and weeds generally offered too much competition for the emerged tung plant to grow satisfactorily.

Some selections from the breeding program were desirable in every respect except they would not reproduce uniformly from seed. At that time bud grafting was expensive, slow, and required that the tree be kept an extra year in the nursery. Consequently, only those selections that could be propagated from seed were released as named varieties.

In later years, more emphasis was placed on breeding a late-blooming variety. Loss of crops due to late spring freezes has historically been the major cause of decreased yields. Much progress has been made in this area, and new late-blooming varieties are nearly ready for release.

Tung Organizations

IN addition to the impetus the American tung industry received from effective research programs, it has been well represented for the past 37 years by organizations attentive to the welfare of growers and processors in legislative and economic matters and in international trade. The oldest of these is the American Tung Oil Association, which was organized in 1933 and deserves a large measure of credit not only for creating interest in tung growing during the early days, but also for representing and promoting the industry and encouraging the use of its quality product.

The National Tung Oil Marketing Cooperative was organized to assist the growers in marketing their crops more advantageously. When oil was selling on the open market well above the Government support price, cooperative marketing was the most profitable method for the grower members. But as market prices decreased to support levels, the function of the National Tung Oil Marketing Cooperative became dormant. The organization is still chartered, however, and may be useful in the future.

The Pan-American Tung Research and Development League is sponsored by the tung growers of the United States and Argentina. This is strictly a research organization concerned with oil utilization. A laboratory is operated on the campus of the University of Southern Mississippi and is staffed with two research chemists, one post-doctorate and three fellowships at the university. It is believed that only through the findings of this laboratory has tung oil been able to maintain its position in consumption in relation to other fats and oils. The budget of this organization is sustained by dues from the industry.

American tung growers, naturally, feel indebted to all those whose efforts helped the industry in so many ways. Undoubtedly, the commercial industry would not have been established or survived without the interest and support of the tung organizations, the State and Federal research programs, and the congressional delegations from tung-growing areas. The production research program, in particular, is recognized throughout the horticultural world as one of the most productive and scientifically sound ever conducted.

The noted horticulturist, W. H. Chandler, has written: "Scientific knowledge of the tung tree has advanced more rapidly than has knowledge of any other orchard species in such a length of time. A program of research by well-trained workers under intelligent and courageous administration has made study of the tung orchards of the Gulf States exceptionally interesting." There is no doubt but what certain methods and procedures used will become standard practices in other areas.

Status and Prospects

AT one time, the domestic tung industry encompassed over 200,000 acres of orchards. This included some acreage planted in "frost pockets" and on unsuitable soil types. Most of the orchards remaining

in production today are located on good tung soils where air drainage provides some frost protection.

It must also be pointed out that when tung was a fast-growing industry the price of tung oil ranged from 35 to 40 cents per pound. Mills were paying from $90 to $110 per ton of whole fruit. The cost of production, labor, equipment, and management was but a fraction of today's costs. Through cheap land and low-production costs, tung was the most profitable cash crop grown in its climatic area.

All of the tung oil produced during World War II was directed by the Government toward the war effort. At that time, commercial consumers conducted a research program for the purpose of replacing this natural drying oil with synthetic materials or combinations of other less valuable vegetable oils. Tung oil has never been able to regain its prewar place in the vegetable oil markets. Also, two South American countries, Argentina and Paraguay, have become principal tung-producers—each having more acreage than the United States. At present, there is no restriction on imports.

The open market price of tung oil has been fluctuating between 22 and 26 cents per pound. The Government support price has been around 25 cents per pound. These prices for the oil will reflect a gross value of about $72 to $80 per ton of whole fruit to the growers. Thus, the economic outlook for tung is not as bright as it was in the 1930's and 1940's.

About 40,000 acres of bearing orchards were completely destroyed by Hurricane Camille on August 17, 1969. This storm carried winds of a velocity of 160 miles per hour and cut a swath directly through the heart of the tung-growing area of Mississippi. These orchard sites had to be completely cleared of debris before the land could be put to any use. Most of this acreage clearing will be complete by the winter of 1970.

What future lies ahead for the American tung industry will depend to a great extent on the attitude of growers and farmers during the next 12 to 18 months. At present—now that the shock of Camille has dissipated—there are hopeful signs that grower attitude will be favorable. Nurseries were planted in the spring of 1970, and new orchards are being set-out—principally of the new, late-blooming selections—although it appears that many of the new orchards will be in the 50- to 100-acre class rather than 500 to 1,000 acres. Furthermore, a large custom mill is continuing to operate for crops produced in Louisiana, Alabama, western Florida, and eastern Mississippi. Grower organizations are still strong, and will continue to serve the tung industry.

In a way, the introduction of tung growing to the United States was a godsend to farmers in the Gulf Coast states, because it came at a time when they were looking for a cash crop suitable for the large acreages of cut-over pine. Tung proved to be the best, and this bit of agricultural history is not likely to be forgotten by the present generation.

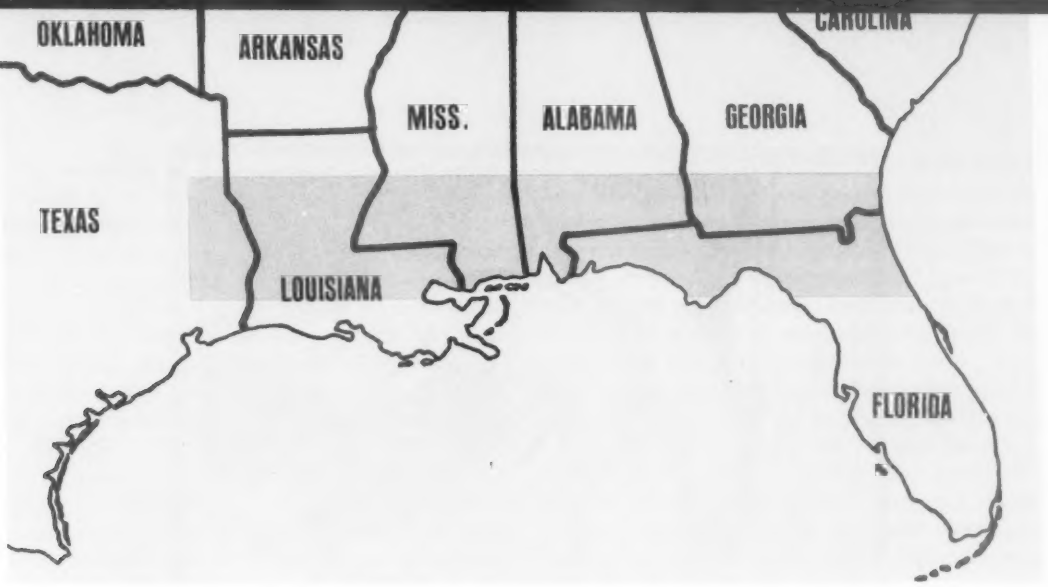
It must be emphasized that tung is well-suited for the climate where it is grown and particularly to the sandy-clay rolling terrain soils. During the hot summer months, annual crops and pastures are at times severely affected by dry weather. Irrigation is not practical on these soil types and terrain, and tung trees, of course, can be grown without irrigation.

Tung farmers once produced only one crop on their farms. For the past decade, the trend has been to diversify with beef cattle and to plant low-lying

CLIMATIC RANGE OF TUNG

The northern range of practical commercial tung production in the United States is 75 miles north of the Gulf of Mexico. Although test orchards were originally planted much further north than this, annual crops could not be produced because of winter killing, early fall freezes before the trees had entered dormancy, or late spring freezes after the trees began growth.

Tung, Aleurites fordii, *is limited to a southern boundary because it is a deciduous tree that goes into a dormant state during the winter. It must be subjected to a temperature of below 45° F. for about 400 hours to cause it to break dormancy in a uniform bloom. Thus, the southern boundary for commercial tung production is about 29° to a northern line of about 31° latitude. The species* Aleurites montana *could be grown south of 29°, but profitable crops are unlikely because of other production problems in that area.*



The practical tung-growing area in the United States lies between 29°40′ and 31°20′ north latitudes.

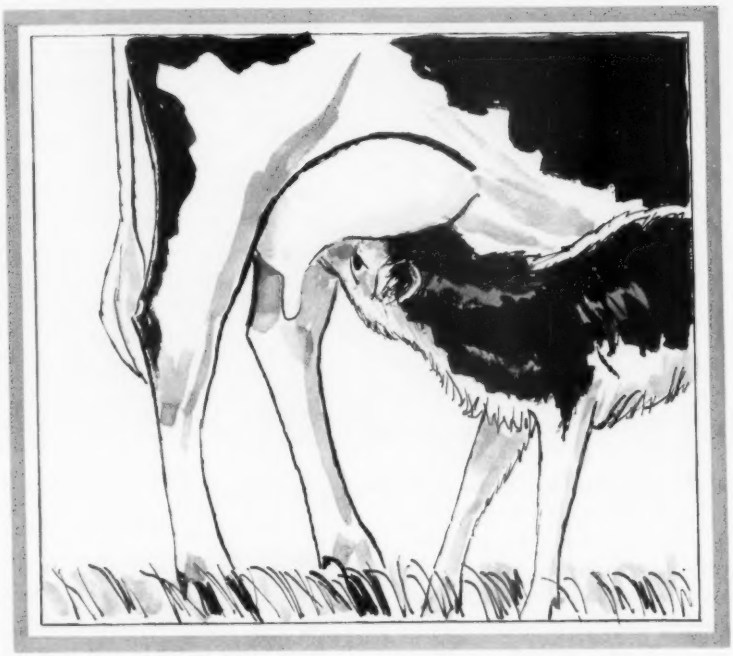
land to permanent pastures, feed grains, or soybeans. Upper land that was unsuitable for tung due to poor soil types has, in many cases, been planted to pine timber. Thus, it will be possible for many tung growers to sustain their farms while a newly planted orchard is brought into production.

As to the status and future of research on tung growing, it should be pointed out that the number of science-man-years devoted to production research had declined before Camille struck—*but only because most of the immediate practical problems had been solved.* However, a number of perplexing problems of a basic nature still remain unsolved. For example, the enigma of biennial bearing (actually, one heavy crop followed by a lighter crop) has not yet been studied. Furthermore, no one has as yet investigated the unusual requirement of a tung tree for a 400-hour period of below 45° temperature in order to break dormancy. Needed also is a late-blooming variety with a high oil content—preferably one that can be propagated vegetatively.

It is conceivable also that greater emphasis on utilization research could open up wider usage of tung oil. Past utilization research—mostly by private interests and producer-affiliated organizations—has led to a wide array of uses beyond that as a drying oil for paints and varnishes.

Prime uses for tung oil for which adequate substitutes have never been developed are coating and insulation of fine electrical wiring, high quality varnishes and lacquers, special use printing ink, and coatings for the interior of metal containers used for beverage and food. Also, protective coatings containing liberal amounts of tung oil have proved to be the best protection against salt water and air along the seacoast and for off-shore oil-drilling equipment. Experiments now underway by the Pan-American Tung Research and Development League on the use of tung in electro-coating of metal surfaces show much promise as a potential for markedly increasing the volume of tung oil consumption in the future.

From an economic standpoint, some indication of the future of the American tung industry may be taken from the fact that domestic consumption has remained relatively stable during the past decade, while consumption of linseed oil as a drying oil for protective finishes declined. This is a minor point, perhaps, but it emphasizes the quality aspect of the product—a factor too often forgotten in the current trend toward the search for cheaper substitutes for natural products. Tung oil is valuable to man because, among the vegetable oils, it contains a high content of eleostearic acid—the ingredient that imparts the drying characteristic. It is significant to note also that the U.S. product contains a higher percentage of eleostearic acid than that from South America—about 82 percent. This quality aspect of the domestic product may well be one of the payoffs resulting from an all-encompassing research program which played a major role in developing the potential of a new agricultural crop.



New Concepts In Calf Scours

FLOYD W. FRANK

CALF scours, a highly infectious diarrheic disease, is a major cause of losses in new-born calves. Its etiology is varied. Although for many years the principal cause of the disease has been attributed to *Escherichia coli,* a great number of microbial agents are now known to be causative factors. The following is a partial list of agents which have been shown to have etiologic significance in causing diarrhea and death in young calves:

Bacteria:
- *Salmonella dublin, S. derby, S. typhimurium, S. enteritidis* and many other species.
- *Escherichia coli* (over 5,000 known serotypes, most believed to be non-pathogenic, however).
- Proteus (several species)
- *Providencia stuartii* (possibly more than one serotype).
- Paracolons

Bacterial Toxins:
- *Clostridium perfringens* types B, C and D

Viruses:
- B.V.D. virus
- HADEN virus
- I.B.R. virus
- Adenoviruses
- Enteroviruses

Chlamydia (PLT)
- This is the group of micro-organisms to which the Epizootic Bovine Abortion (E.B.A.) and Enzootic Abortion of Ewes (E.A.E.) agents belong.

Mycoplasma (PPLO)

Fungi

Evidence that all of these agents are incriminated is based on (1) isolation from outbreaks of the disease, (2) serological test results, or (3) reproduction of the disease in calves by either natural or artificial inoculation. No single agent, however, seems to be able to produce disease in calves comparable in severity to that seen in natural outbreaks of calf scours. It appears likely, therefore, that, even with this long list of agents, the cause of calf scours cannot really be fully explained.

At present we have only a very limited knowledge of the distribution of many of these agents. For example, an enteric bacterium, *Providencia stuartii,* has frequently been recovered in the Caldwell area of Idaho from intestinal content of calves that died from calf scours. Distribution and incidence of the disease due to this organism, however, seem to be limited to an area within about 50 miles of Caldwell, Idaho. Similarly, a bovine enteric adenovirus appears to be the cause of diarrhea on one ranch in eastern Oregon.

To test the severity of *P. stuartii* under controlled conditions, 18 newborn beef calves were inoculated with the pathogen. Twelve of the calves developed diarrheic conditions. None of the scouring calves were treated, and all but two of them recovered. In a control group of 15 calves that were not inoculated, only two mild cases of scours were noted, and both of these recovered. Although 12 calves scouring out of 18—and 2 deaths—may seemingly reflect a serious incidence of the disease, the situation cannot be compared with the problem as observed in the field—particularly in view of the fact that the diseased calves were not treated.

If one views the situation realistically, it can safely be said that no single diagnostic laboratory or research institution exists which is capable of evaluating the presence and involvement of all or even most of the agents that have been incriminated as causes of calf scours. Everyone, it seems, is interested in isolating a new agent. A researcher gets all tooled up to look for a particular kind of pathogen—often in a way that excludes even the possibility of isolating other pathogens—and invariably he will find the kind of causative agent he is looking for. One State hired a virologist, and he found a virus. Another State employed a person interested in *Chlamydia,* and eventually he found *Chlamydia* involved in neonatal diseases of calves. Idaho has not, until recently, had a virologist on the staff, so we have incriminated a bacterium. It will probably be a long time before all of our present knowledge on etiology can be put in proper perspective, although Western regional research projects W–88, Enteric Disease of Neonatal Calves (terminated June 1970) and W–102, Reproductive Performance of Beef Cattle, give a sense of direction and keep all researchers up-to-date on new findings.

Paralleling the current interest in discovering new causative agents is that of developing an effective vaccine. Most cattlemen would welcome the development of a vaccine or bacterin that would give some promise of preventing calf scours. As a matter of fact, vaccination of the dam and subsequent transfer of immunity to the calf via the colostrum is technically possible for most of the known causative agents. However, the number of agents involved would make vaccination against all of them impractical. A more logical immediate step would be to determine which agents are really the most important causes of calf scours. This is not a simple task.

Recently one of the mid-western states issued a press release announcing the isolation of a virus from calf scours and indicating that a vaccine was being developed. This announcement prompted a number of inquiries from Idaho cattlemen and veterinarians who were interested in using the vaccine as soon as it was available. At the time, our department did not even know if that particular virus was present in Idaho. This example well illustrates the problem faced by veterinary scientists. Yet while it is true that surveys are needed to determine which agents are important causes of scours, a more immediate concern should be the development of practical diagnostic tests for use in accomplishing these surveys. Unfortunately, our technology for isolating new agents or even developing new vaccines has outrun our interest or ability to develop new diagnostic procedures.

A Multiple Etiology

BECAUSE of the many agents believed to contribute to the calf scours complex, it would seem logical to investigate a possible multiple etiology such as that postulated and later proved valid for shipping fever of cattle. In attempting to come up with a working hypothesis upon which to base future research, the following formula is presented:

Susceptible animal + stress + virus + bacteria or other agent = calf scours

This is essentially the same formula postulated for the etiology of shipping fever; the only difference is that there are many more infectious agents to plug into it.

Susceptible Animal

SINCE some animals appear to be more susceptible to calf scours than others, then it seems logical that others may carry some natural resistance to the disease. A number of factors justify efforts to support this hypothesis. In the first place, inherited natural resistance to disease has been shown to occur among other animals, for example, resistance to internal parisitism in sheep. Second, in most calf scours outbreaks, some animals are apparently unaffected. These animals may be naturally resistant. Third, so many infectious agents are suspect in causing calf scours that specific immunity through vaccination of the dam seems impractical—even if technically possible—until we can determine which agent or agents are most important. And finally, if one could find some readily identifiable characteristic associated with, or indicative of, natural resistance, it would then be possible to attempt to develop resistant lines of cattle.

In order to test this hypothesis, the Idaho Agricultural Experiment Station selected 40 cows from 2 herds with histories of calf scours. Twenty cows, designated susceptible, had low serum levels of gamma globulin and histories of having calves which scoured. The other 20 head, designated resistant, had high serum levels of gamma globulin and had histories of having calves which did not scour. These cows were then the subjects of a 4-year study [1] in which they were bred as 2 separate herds and used in studies to determine total protein, globulin levels, and antibody titers in serum and colostrum of the cow and in the pre- and post-nursing serum of the calf as they related to resistance to challenge with pathogenic *E. coli*.

Although this study did not prove our hypothesis, it did yield some interesting data:

1. The two groups of cows and their progeny appear to be retaining their respective standings for gamma globulin levels.

2. After dissipation of maternal globulins, total protein and gamma globulin in all animals continually increased throughout life.

3. The incidence of scours in the two groups was relatively low and no significant difference were discernable. However, when calves were withheld from nursing for 12 hours, there was a significant difference in the incidence of scours (following *E. coli* inoculation) when compared to calves that nursed early. Calves whose colostrum feeding was delayed tended to have lower concentrations of gamma globulin even after receiving colostrum. The same relationship held for levels of serum antibody.

4. The intestines of calves inoculated orally at birth with live *E. coli* were rapidly colonized by the inoculum organism. However, this strain of organism constituted a progressively smaller percentage of the isolates as the calves grew older. No isolations of the inoculum serotype were made from yearling calves inoculated at birth.

There were a number of negative aspects in this experiment. We failed to reproduce fatal disease in calves orally inoculated with supposedly pathogenic *E. coli* serotypes except in those from which colostrum was withheld. We failed to establish that there was any real difference between the progeny of cows designated as susceptible or resistant. But we did clarify much basic information on resistance to disease in young calves. We did affirm the importance of early colostrum feeding to the health of the calf. It is possible that some factors which are operative in many of our calf scours outbreaks may influence the calf's ability to absorb antibodies. It is known that the intestinal cells do not distinguish proteins; feeding of milk will block the ability to absorb antibodies.

A point of some importance is that the first organisms to be taken in by an animal after birth have no competition and therefore can rather completely colonize the gut. If we are going to attempt to inoculate the calf with favorable organisms such as *Lactobacillus acidophilus*, perhaps the inoculum should be given before the calf nurses.

Stress

STRESS is the sum of all nonspecific biological phenomena brought on by adverse external influ-

[1] Supported in part by U.S.D.A., A.R.S. Contract No. 12-14-100-8300(45), Investigations on resistance to enteritis (scours) among young calves: The role of gamma globulin or other serum proteins and specific antibodies.

ences, including damage and defense. Evidence is pointing more and more to the importance of the role of stress in coping with the calf scours problem.

The cattle industry is gradually, almost insidiously, moving to practices that tend to increase animal stress: less space per animal unit, earlier calving, more intensive feeding. The experiences and accompanying problems of other livestock industries—swine and poultry—that have gone the same route are almost completely ignored. Some of the simplest sanitation measures are not practiced. Even though water has historically been a major vehicle for spread of enteric disease, often there are no arrangements for sanitary watering. Even though we know that most of the organisms causing enteric disease are shed in the feces and transmitted orally, cows and calves are still fed hay on the ground when in confinement. Even though we know that earlier calving exposes calves to severe weather stress and extremely unsanitary conditions, only minimal steps are taken to reduce this stress.

Stress factors undoubtedly deserve much more attention than they normally receive by research planners. Agricultural engineers and animal scientists need to work together to develop housing and management systems that will minimize stress. It is quite unlikely that we can provide a degree of immunity to all the agents involved in calf scours that will stand up in the face of stress.

Bacteria

THERE is an abundance of evidence that *E. coli* and related enteric bacteria are major contributors to the calf scours problem. But what complicates the situation is that these bacteria do not always follow the usual patterns for the exchange of genetic material which is assumed to apply to all bacteria—that is, reproducing only by simple binary fashion.

Under some circumstances, one strain, serotype, or species acts as a donor of genetic material to another. The progeny of the recipient then assume some of the characteristics of the donor. This appears to be the mode of transmission of the so-called R factors for resistance to antibiotics. Thus, a nonpathogenic enteric bacterial strain that is antibiotic-resistant can transfer its capacity to resist particular antibiotics to a pathogenic antibiotic-susceptible strain.

Other characteristics have also been shown to be transferable in this way. Thus, one might expect the enteric population of the gut of an animal to be constantly changing and, in fact, this appears to be the case. This change is perhaps partly in response to the development of immunity of the host. The development of a strong immune reaction in response to exposure to *E. coli* was shown in the cows during the second year of Idaho tests.

In attempting to incriminate enteric bacteria as the cause of a particular episode of scours, one must recognize that the fecal discharge of a calf may not be indicative of what is causing the disease. Antibiotic sensitivity tests on fecal material may be meaningless. The accepted theory is that *E. coli* causes enteritis by virtue of runaway growth in the upper small intestine, which normally is rather free of coliforms. The population of the pathogenic strain in the feces may not be indicative of that of the upper small intestine.

In studying enteritis due to *S. typhimurium,* the organism can rarely be recovered from feces, but can rather routinely be recovered from visceral organs. Thus, if one suspects salmonellosis he should be collecting spleen, gall bladder, liver and viscera lymph nodes for culture.

Viruses

RESEARCH has shown that a number of viruses can cause enteritis or pneumonenteritis in calves. In most experiments, the disease produced has been rather mild. At the moment it seems expedient to theorize that viruses may serve as the triggering agent for scours in calves much as is the case in shipping fever. However, the theory regarding runaway bacterial growth with production of irritating toxins also appears attractive at this time.

Other agents such as chlamydia, mycoplasma, protozoa, and fungi have also been incriminated or are suspect.

A Realistic Approach

PRACTICING veterinarians and cattlemen are quite properly looking to research to solve the calf scours problem—some of them perhaps hoping for a magic bullet-type antibiotic or an all-purpose vaccine. No such panacea, however, is on the horizon.

More and more outbreaks of disease, particularly scours or diarrhea, fail to respond to the commonly

employed antibiotics. One of the reasons, of course, is that some of the organisms have developed resistance to the antibiotic being used. Another reason is that some of the cases are the result of viral infections, which are unlikely to respond to antibiotic treatment.

The mechanism of development of antibiotic-resistant strains is partly a matter of genetic selection. When a bacterial population is exposed to an antibiotic—and when the entire population is sensitive to the particular antibiotic at the concentration being used—all the organisms are inhibited or destroyed. However, if some of the bacteria are resistant to the antibiotic at the particular concentration being used, they survive and multiply. If they pass this resistance character to their progeny, an antibiotic resistant strain of that particular organism develops.

As to the vaccines—it seems likely that effective ones can be developed for most causative organisms. But the big question is where to apply which vaccine. Furthermore, as previously noted, relying on a specific vaccine for each pathogen is rather impractical.

Where, then, does the solution lie? The situation quite logically calls for a realistic approach on the part of all three interested groups—cattlemen, veterinarians, and researchers. Certainly, the bank of knowledge concerning calf scours is greater than it was even a decade ago. Much potential exists not only for expanding each facet of new knowledge but also for putting into practice the wise management factors that we know will pay dividends.

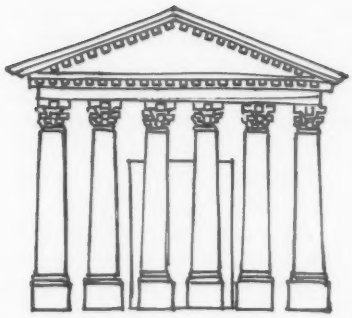
The need for practical diagnostic tests and properly staffed laboratory facilities to carry them out cannot be overemphasized. Furthermore, study of the epidemiology or epizootiology of the disease agents that cause calf scours has been neglected. Unless the concerned research agencies follow the calf scours problem year after year—determining the agents involved in each succeeding outbreak—it is possible that we may be continually basing our disease prevention programs on the disease we have just had rather than the one we are likely to have in the future.

Much remains to be learned about the nature of immunity to this disease in a new-born calf. Which antibodies in colostrum are really important to immunity? What factors affect the calf's ability to absorb antibody from the gut? At what age can the fetus *in utero* respond by development of effective immunity? It may be possible to vaccinate the calf in the uterus so that it would be born with active immunity.

More knowledge is needed as to the changes that occur in a calf's body as a result of scours so that effective treatments can be devised to reverse these changes. The industry's almost single-minded reliance on antibiotics in treatment fails to take into account that the antibiotic combats only infection. It does nothing to reverse the changes that result from infection such as dehydration and inflammation.

Research on stress has been quite meager. If stress is truly a factor in the etiology of scours—and there seems little doubt that it is—how can it be minimized? Any system that provides adequate shelter protection without concurrently providing a sanitary environment defeats the purpose of the whole plan.

And finally, it seems likely that studies on the role of nutrition of the dam would give further insight as to the causes of calf scours. Some pioneering research has already been started, but this field of activity needs much deeper exploration.



FORUM

THE LEGITIMACY OF COLLEGES OF AGRICULTURE

THE word *legitimacy* has many connotations. In contrast to its use in a parentage context, legitimacy of an organization in society is functional; that is, it can increase or decrease. In such a context, an organization rarely loses all its legitimacy and becomes illegitimate; if it did, the occasion would be catastrophic.

I do not believe that the colleges of agriculture are in any real danger of losing their legitimacy. But I do believe that in the coming decade they may face the unhappy prospect of becoming less legitimate, unless certain trends are checked.

Most of my ideas about legitimacy come directly from or have been suggested by a very provocative paper written by Kenneth Boulding entitled, "The Legitimacy of Central Banks." This brief paper was one of a series of papers prepared for the Steering Committee on Fundamental Reappraisal of the Discount Mechanism appointed by the Board of Governors of the Federal Reserve System.

The legitimacy of an organization is a rather sensitive subject. One can hardly discuss the legitimacy of anything without seeming to threaten it, for a great deal of legitimacy depends upon things taken for granted and not discussed at all. Legitimacy is important; if a person or an organization loses its legitimacy it can no longer sustain itself in the social system. No amount of wealth or power can keep an organization alive if there is widespread denial of the legitimacy of its role in society. The reason is that continual performance of any role requires an acceptance of legitimacy on the part of those who are affected. As Boulding states: "To use a rather crude illustration, a bandit can take your money once, but anyone who wants to take it every week either has to be a landlord or a tax collector."

For example, the ability of a college of agriculture to receive inputs from the State it serves depends upon the willingness of the people to give money, time, and support to the university. They will not do this regularly and continuously unless they regard the college as legitimate. On the other hand, if the recipients of the knowledge and other benefits of the college do not view its role as legitimate, they will not accept the knowledge and benefits and thus it would not be serving a useful purpose.

Six Sources of Legitimacy

BOULDING distinguishes at least six sources of legitimacy: (1) Payoffs of the organization in question, (2) willingness to make sacrifices for the organization, (3) age, (4) mystery, (5) ritual or artificial order, (6) alliance with other legitimacies.

If an organization provides a society with a good payoff relative to inputs, its legitimacy will increase, especially in the long run. Or, to state the premise negatively, an organization that pays off very poorly, demands a good deal from the people and gives very little in return is likely to lose its legitimacy in the long run. The relationship is certainly nonlinear and

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This Forum article was adapted from a paper presented by the author, Dr. R. J. Hildreth, at the Awards Banquet of Iowa State Chapter of Gamma Sigma Delta, April 1970.

quite complex. A college of agriculture may be useful and pay off well, but this quality does not necessarily give it legitimacy, although it helps a great deal.

One reason why payoff alone is not sufficient is that often an organization can obtain legitimacy through bad payoffs or sacrifices. An organization can obtain legitimacy if people are willing to sacrifice for the organization. Most of us are willing to sacrifice for the United States. Many people connected with a State university are quite willing to sacrifice for it. Boulding identifies this kind of operation as a one-way transfer from one decision unit to another. This differs from exchange, which is a two-way transfer. The sacrifice system is very complex because often the sacrifices are self-justifying. If *A* makes sacrifices for *B*, it is very hard for *A* to admit to himself that these sacrifices have been in vain. Admitting that such sacrifices have been in vain threatens his own identity, which is probably the greatest threat any person can feel. Thus, the tendency is to continue to make sacrifices even after any expected long-run payoff has failed to materialize. But at some point, the terms of trade may become so bad that they cause a breakup between *A* and *B*.

A third source of legitimacy is age. An organization can build up legitimacy just by existing. However, this function is not necessarily linear. Age increases legitimacy up to a point, but beyond that point the organization may become middle-aged or old-fashioned and legitimacy declines. Then as time goes on, the organization might become an honored institution, and legitimacy would increase. However, this last phase of increasing legitimacy may come posthumously.

A fourth source of legitimacy is mystery. Something that is only dimly understood as grand and magnificent often acquires an image of legitimacy in the minds of those who do not understand it. To many people, the discovery of new knowledge through research is something of a mystery—not well understood but conceived in general to be good. Because of this, people are willing to support research and accord research organizations sizeable amounts of legitimacy—often in the absence of much in the way of tangible payoff.

A fifth source of legitimacy is ritual or artificial order. Mankind has always feared uncertainty—of weather and crops, of accidental injury or death, of disease, of the future. One way to deal with this fear is to create a semblance of order through regularly repeated rituals, liturgies, and human law. As Boulding points out, "To say that law and ritual are artificial order is not in any sense to deny them validity, nor does it mean that these artificial orders are arbitrary. When they are successful it is precisely because they reflect an order in the real world, whatever that is." Colleges of agriculture have received a certain amount of legitimacy because they provide information which enables farmers and others to deal more adequately with uncertainties of weather and crop growth and provides ways of understanding events that otherwise would appear to be random. There is also some ritual in the use of test tubes, plots, computers, and tests of significance in a college of agriculture.

The sixth source of legitimacy is the alliance of an organization with other organizations that have high legitimacies. It is possible for a college of agriculture to increase or decrease in legitimacy as its university increases and decreases in legitimacy, simply because it is closely associated with the university. Also, insofar as science, or farming or agriculture increase and decrease in legitimacy, the legitimacy of the college of agriculture will be affected.

Trends in Agricultural Colleges

WHAT will be the trend in legitimacy of the colleges of agriculture in the coming years? This is a question of some interest to students and staff of the colleges, and in my judgment it is a significant question for the public. The colleges need to have legitimacy from a number of sources: the general public including the agricultural industry, the rest of the university, and the U.S. scientific and university community including other colleges of agriculture. I shall go through the list of sources starting at the sixth source and work backwards toward payoff in an attempt to speculate on the trend in the legitimacy of the colleges of agriculture for the general public. I think it is more important to examine the legitimacy of agricultural colleges from the view of the general public than from the view of the scholarly and scientific community at this point in time.

A significant source of legitimacy for agricultural colleges has been their relationship to the universities, to science, and to agriculture. As I perceive the

current scene, the legitimacy of all of these institutions has been declining in the minds of the general public. There has been a significant loss of good will toward universities because of student unrest. Government support of research has been declining, and future support for higher education appears likely to go to community or junior colleges rather than 4-year colleges or graduate schools. The public has been burdened with many decades of costly surplus disposal programs for agriculture. The portion of the national economy dependent upon farming is declining; for example, by 1980 it is likely that employment on farms will be less than total unemployment in the United States, even during periods of high economic activity. Environment, urban, and city problems are of growing concern. Thus, the legitimacy of the colleges of agriculture probably will decrease or at least will not increase as a result of its alliance with other organizations. The magnitude of the decrease may not be great, but the important point is that the trend is clearly negative.

The legitimacy of colleges may increase somewhat because of their continued ability to create artificial order or reduce uncertainty, especially from the point of view of the agricultural industry. But some problems are developing. Colleges of agriculture have been considered the "high-priests" of improvement in agriculture technology and knowledge. Most of society has held the view that such increases bring positive benefits to their generation and succeeding ones. But this optimistic view is being questioned. Increasing numbers of people are concerned about the effect of technology on environment, on the distribution of economic power in agriculture, and that the ability to dominate nature is linked with the domination of man. Such questioning is not limited to agriculture but is applied to all science and technology. If this view should grow, then the role of "high-priest" would lead to a negative reaction and a reduction in legitimacy. This development relates to payoff and will be discussed later.

The colleges of agriculture perhaps are in the middle-aged category. They are certainly not old enough to be antique and beloved for their oldness. On the other hand, they are too old to have the special legitimacy of infants, young people, or new fashions. On balance, the age source is probably slightly negative.

Sacrifices have never been a significant source of legitimacy for colleges other than from dedicated workers and scientists who are committed to development and distribution of agricultural knowledge. Most colleges of agriculture have the good will of many of the people of their State and the Nation. But the number of people willing to really sacrifice for it never has been large and probably will not increase in the future.

The Payoff Issue

IT is my thesis that the payoff source of legitimacy is the crucial variable for the future. If this thesis is correct, then the decisions made by individual workers and the administrators of the college are significant. For example, the choice of research problems and the strategy in funding lines of research can have significant impacts on payoff. I do not wish to propose or suggest that there is an easily determine optimum strategy to maximize payoff. Investments in the research enterprise made now oftentimes do not yield results until years later; thus the best strategy is uncertain. Also, there does not appear to be a straight line relationship between inputs and outputs. Chance enters into the picture. The holes that are drilled sometimes turn out to be dry. But payoff can be influenced by choice of research projects.

The payoff issue can be viewed from many perspectives. One of them is the distributive aspect of the payoff. Who receives the benefits from colleges of agriculture? The traditional answer is that it has gone to farmers, and we find farmers thinking they have received much of the payoff. But even here a distribution question arises. For example, did the payoff from, say, Iowa State University, go to farmers in Iowa or farmers outside Iowa? Did the farmers in Southern Iowa receive more payoff than those in Central Iowa?

Another group who may have a different perspective of the payoff from the agricultural colleges is the processor of agricultural products. The same piece of research may have a very low payoff for the processors but a very high payoff for farmers. The input suppliers to agriculture have a different perspective. Oftentimes there are conflicts between the groups that comprise the agribusiness sector of our economy. What is viewed as a high payoff by one part of agribusiness may be low for others. On the other hand, certain kinds of payoffs will be con-

sidered high by all three sectors.

Then there are the consumers. Most economists argue that the payoff to consumers from agricultural research and education has been very high although many of them did not realize it. But even within the consumer group there are distributional questions. Should more research and education be done that will be useful to low-income consumers rather than high-income consumers?

Another group of people that might have a different perspective of payoff are residents of rural areas who are not engaged in agriculture. They may view the payoff from the agricultural colleges as rather low, and feel it should be higher per unit of input; perhaps higher in absolute terms.

Some very difficult questions are involved in making decisions about research and education in terms of its distributional effects. It would be very nice if we could state with assurance that successfully completed program research and education will benefit the Nation. But this is not always the case. I am less and less convinced that we can even say that a particular piece of research will greatly benefit all of agriculture because of the distributional effects for the diverse groups that make up agriculture.

Another perspective in viewing the payoff is the source of funds. Practically all of the funds that go to the colleges of agriculture come from public rather than private sources. That is, they come largely from Federal or State Government as opposed to private firms. Certainly there is some support for research from private firms but it constitutes a very small amount of the total funds. It seems somewhat axiomatic that if the effort of the colleges of agriculture is paid for by public funds its output should benefit the public.

One of the quickest ways I know to reduce the legitimacy of a college of agriculture is to use public money for research and education that has only private benefits. If the output of research is used only by large firms for their own benefit at the expense of the public, it will not be long before public sources will be unwilling to provide the funds. Much information developed by research is used by private firms, but with a competitive market economy, this use increases the well-being of the general public. However, this does not always happen automatically. Unless the public perceives a favorable payoff from the use of public money, it will not continue to support agricultural colleges.

Negative Effects

THIS discussion of public benefits from public funds holds under the assumption that research and education is a positive good which increases with time; in other words, the payoff function has only positive coefficients. A number of writers believe that technology poses a domination of its own, although it is necessary to free men from domination by physical wants. It is pointed out that new technology makes new opportunities for mankind, but it also generates new problems for them. Technology has both positive and negative effects; both are intertwined and cannot be separated.

These ideas are becoming more prevalent among the general public. One can easily read them in the current dialogue over environmental quality, the consumer movement, and quality of life.

According to Don Price, the direct negative effects arise because science is not eager to undertake to solve the problems of society as society would define them. These negative side effects flow from science's insistence on defining its own problems, which leads to too narrow definitions and failure to consider auxiliary effects. Science and society has put a high value on individual decision making in science and thus lives with the creation of negative externalities.

Societal Wisdom

A REPORT of a committee at the University of Wisconsin published in the March 20, 1970 issue of *Science* suggests that the academic tradition of the freedom of inquiry can be effective only with the validity of one or more of the following assumptions: "(1) That a kind of societal wisdom will constitute a free market of ideas and skills in which the laws of supply and demand will regulate the 'search for truth' so as to produce the truth most needed; or (2) that the leaders in the 'search for truth' have the wisdom to place their efforts where they are most needed, and to integrate new facts into a comprehensible pattern of new wisdom; or (3) that the academic 'search for truth' is mainly a didactic exercise in that the byproducts are either harmless or literally stockpiled until they can be properly harnessed."

The committee answered the question: "What

are the purposes of higher education?" in the following manner:

"The primary purpose of the university
Is to provide an environment
In which faculty and students
Can discover, examine critically,
Preserve, and transmit
The knowledge, wisdom, values
That will help insure the survival
Of the present and future generations
With improvement in the quality of life".

Such a statement of purpose appears to deal well with the issues raised about automatic progress through the creation of new knowledge. It provides for examining external diseconomies as well as the direct economies caused by the production of new knowledge.

It may be that the concepts of payoff by the public will more and more include the negative benefits as well as the positive benefits and that both will necessarily be included in the payoff function. Seldom in the calculation of the benefits from new knowledge have we included a negative factor in the equation. Inclusion of negative factors may well lead to quite different priorities and strategies for colleges of agriculture, as well as the total university.

Is it not time, then, for the faculty and staff of the colleges of agriculture to consider the trend in their college's legitimacy? Certainly, it would seem to be very difficult to keep legitimacy moving along at the same level that it has in the past. Therefore, if it is not increasing, it most surely must be decreasing. Can we afford to let this happen?

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U.S. GOVERNMENT PRINTING OFFICE : 1971 O - 409-219

AGRICULTURAL SCIENCE REVIEW is a critical review journal designed to provide a common point of understanding among agricultural scientists by publishing authoritative commentary on the current state of agricultural research. *Review* does not publish primary research reports. Yearly subscription rate is $1.25, domestic; $1.50, foreign. Single copies are 35 cents. Subscription orders should be sent to the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.